MODERN BUILDING PRACTICE

AN UP-TO-DATE AND PRACTICAL WORK DEALING WITH THE DESIGN, PLANNING, CONSTRUCTION, AND EQUIPMENT OF MODERN BUILDINGS

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VOLUME IV
EQUIPMENT OF BUILDINGS

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CONTENTS OF VOL. IV

PAGE

INTRODUCTION 1

HEATING AND VENTILATION

PART I.—FORMS OF HEATING 3

PART II.—RADIATORS, CHIMNEY FLUES, AND FUELS . . 33

PART III.—CIRCULATING PUMPS AND ACCELERATORS—SIZES OF PIPES 103

PART IV.—PANEL HEATING—BOILERS 167

PART V.—STEAM HEATING—OIL BURNERS 177

PART VI.—VENTILATION—DUST EXHAUSTING—DRYING . 273

PART VII.—BUILDER'S WORK INCIDENTAL TO INSTALLATION OF HEATING AND VENTILATING SYSTEMS . . . 377

PART VIII.—PREPARATION OF ESTIMATES AND SPECIFICATIONS—RUNNING COSTS 424

THE DRAINAGE OF BUILDINGS . . . . . .

PART I.—IMPORTANT CONSIDERATIONS IN THE PREPARATION OF A SCHEME 17

PART II.—BY-LAWS—DRAIN CONSTRUCTION—TRENCHES . 49

PART III.—INSPECTION CHAMBERS, MANHOLES, PIPE-LAYING 129

PART IV.—IRON-PIPE DRAINAGE 209

PART V.—DRAINAGE OF BASEMENTS AND SUB-BASEMENTS . 401

PART VI.—THE ONE-PIPE SYSTEM 517

PART VII.—DRAINAGE FOR ISOLATED BUILDINGS, COUNTRY HOUSES, FARMS, INSTITUTIONS, AND FACTORIES . . 593

SANITARY SURVEYING

PART I.—TESTING DRAINS 44

PART II.—TESTING VERTICAL STACKS 97

PART III.—SANITARY FITMENTS 161

PART IV.—DAMPNESS 186

PART V.—WATER SUPPLY 270

PART VI.—MAKING YOUR REPORT TO THE CLIENT . . 363

SANITARY SCIENCE APPLIED TO BUILDING

PART I.—SUITABILITY OF SITES FOR BUILDING—GENERAL CONSTRUCTION 66

PART II.—PREVENTING DAMPNESS 113

PAGE

SANITARY SCIENCE—*continued*
- PART III.—COLLECTION OF RAIN-WATER 225
- PART IV.—TREATMENT OF WALLS AND FLOORS . . . 326
- PART V.—WATER SUPPLY. RAIN-WATER—USE OF WELLS FOR SUPPLIES—RAISING WATER—CONSTRUCTING A WELL—QUALITY OF WATER 452
- PART VI.—WATER SUPPLY (*continued*). PUBLIC SUPPLIES 529
- PART VII.—WATER SUPPLY (*continued*). CISTERNS—VALVES—PIPES 558

GENERAL PRINCIPLES OF HOT-WATER SUPPLY
- PART I.—DESIGN OF SIMPLE CIRCUITS 81
- PART II.—DESIGN OF SECONDARY CIRCULATIONS . . 145

USEFUL DATA ABOUT COPPER PIPES 127

GAS FITTING AND GAS APPARATUS 193

BENDING COPPER TUBING 235

SANITARY FITTINGS
- PART I.—SANITARY POTTERY—WATER-CLOSETS . . . 241
- PART II.—SINKS, BATHS, AND LAVATORY BASINS . . 353
- PART III.—TRAPS—TRAP VENTILATING PIPES—SOIL PIPES . 574

WATER HEATING BY GAS 257

ELECTRICAL WARMING APPARATUS AND INSTALLATION
- PART I.—DIRECT HEATING 289
- PART II.—INDIRECT HEATING 369

MODERN DOMESTIC KITCHEN PLANNING AND EQUIPMENT . . 305

WATER-SOFTENING APPARATUS AND INSTALLATION . . . 337

COOKING EQUIPMENT AND INSTALLATION 385

MATERIALS USED IN SANITARY WORK 433

ELECTRIC WATER HEATERS AND INSTALLATION. . . . 473

CHURCH FITTINGS 497

LAGGING FOR PIPES, TANKS, AND CYLINDERS 541

ELECTRICAL SERVICES IN MODERN BUILDINGS 545

FIRE PROTECTION IN BUILDINGS. EXTINGUISHING APPARATUS . 570

ELECTRIC LIGHTING SCHEMES 581

STRONG ROOMS AND SAFE DEPOSITS 613

INTERNAL WALL TILING 625

INDEX 627

MODERN BUILDING PRACTICE

VOL. IV

EQUIPMENT OF BUILDINGS

INTRODUCTION

IT is generally agreed that the buildings which are being erected in this country to-day, for domestic purposes, for public service and for commercial use, represent a very high standard of attainment. We believe that the best modern designs will bear comparison with any work which has gone before. To correspond with the improvements in design, great advances have been made in constructional methods resulting in a fabric which is ideally adapted for its purpose.

Unobtrusive but Vitally Important

All buildings, except monuments, are built for occupation, therefore the interior equipment of a building, although it is so unobtrusive to the eye, is of vital importance in the general scheme. Although they may form but a small proportion of the total cost of a building, the essential services—water supply, drainage, gas, electricity, the ventilation system, the lift equipment, the heating and cooking appliances, the refrigerator, the wireless installation—are of vital importance to the comfort of the occupants. This volume has, therefore, been devoted to these highly specialised sections.

The fact that the interior equipment has a profound influence on modern design and construction will be apparent when it is considered that the modern steel-framed structure of seven or more stories would be impracticable without the lift. To quote from the book, *Building to the Skies*, written by one of our contributors, Mr. Alfred C. Bossom, M.P., F.R.I.B.A. :—

"The steel frame of a modern building may be paralleled to the bones in the human body. The arteries, veins and

nerves find their prosaic but indispensable equivalent in the plumbing pipes, soil pipes, circulating pipes, telephone wires, steam and electric conduits, that run to every part of the building, and are so placed and constructed as to make alterations easy and inexpensive. The heating system is not unlike our blood circulation. The ventilating apparatus forms the lungs and the engine-room is the heart of the whole structure."

No attempt has been made in the present volume to convert the builder into a lighting specialist or a lift engineer. Each subject has therefore been treated having in mind the requirements of the architect who designs the building and the builder who erects it.

All the sections of this volume have been written by specialists, who have, however, treated their respective subjects from the point of view of the builder rather than from the point of view of the expert. For example, the by-laws relating to the drainage of buildings have been clearly explained and illustrated by means of pictorial diagrams, which we believe will present the essential requirements much more clearly to the practical man than would be possible by the use of legal phraseology.

The Architect

The architect will find the complete descriptions of the latest systems of ventilation, heating, hot-water supply, convenient for reference; and he will have the satisfaction of knowing that each article has been written by a man who has expert knowledge of his particular subject.

The Builder

Similarly, a man in the building industry, who is, or who intends to become, a master builder will find that this volume contains just that information which he needs to have at his finger-tips ready for immediate reference when occasion arises.

The Sub-contractor

The specialist on lighting, heating and ventilation or lift equipment who uses this work for reference purposes will, we believe, be able in the future better to appreciate the difficulties of the builder.

HEATING AND VENTILATION

PART I.—FORMS OF HEATING

FOR providing the necessary warmth to a building so that the occupants may be comfortable in the severest weather, the architect has a wide choice of methods from which to make a selection. In the small dwelling-house, coal, gas or electric fires are usually considered sufficient, but for a large building it is obvious that the even distribution of heat from a central source is desirable, and this can be obtained by installing either one, or a combination of more than one, of the following systems :—

LOW-PRESSURE HOT WATER
HIGH- OR LOW-PRESSURE STEAM
WARM AIR

Gas-heated or electric radiators are extensively used, but do not come in the category of central heating.

The method of heating chosen depends upon the type of building and the use to which it is put. Initial and running costs, too, are important considerations.

Open Fireplaces

The open fireplace will long remain as an essential feature of the English home. Although it cannot be regarded as an efficient distributor of heat, no one will deny the pleasing effect of a bright coal fire.

Heating Stoves

The slow-combustion stove is often used for the heating of small entertainment halls and similar buildings where there is but a limited amount available for the installation of the heating system. It has the advantages of being easy to install and requiring no skilled attention. On the other hand, however, its use involves the carrying of fuel into the room and the removal of ashes. The scattering of dust in carrying out these operations is a decided drawback.

Warm Air

A carefully designed warm-air heating system is a very satisfactory method of warming a large hall and is one frequently adopted for churches, cinemas, workshops and large entertainment rooms. In a cinema, for

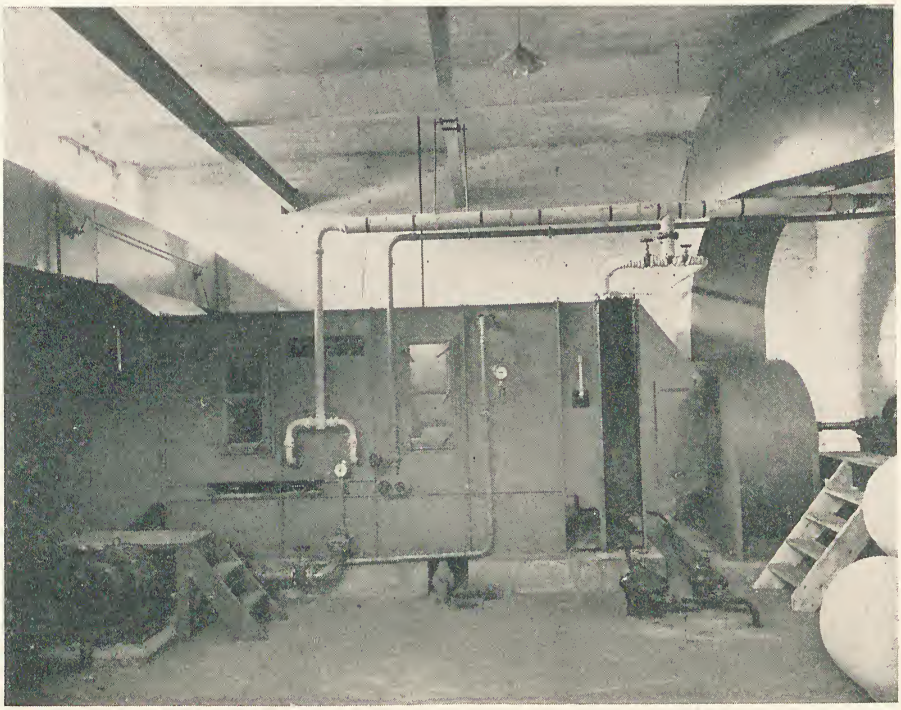


Fig. 1.—AN ARRANGEMENT OF A LARGE AIR-WASHER, HEATER AND CENTRIFUGAL FAN
(*Sturtevant Engineering Co., Ltd.*)

instance, where L.C.C. regulations are complied with, ventilation at the rate of 1,000 cubic feet of air per hour per person necessitates the constant input and removal of a large volume of air. It is not sufficient to allow the incoming air to leak through doors and windows and to rely upon radiators to counteract the effect of cold draughts. It is advisable, therefore, to introduce warm air through controllable inlets arranged to exclude the possibility of any occupant becoming uncomfortable.

The Plenum System

A " Plenum System " is one where warm air is blown into the building at a larger rate than the ventilating system removes it, so that a slight pressure is created. Air leakage through doors and passages tends therefore to be in an outward direction.

The plant usually consists of a centrifugal fan, air-heater and distributing ductwork. An air-washer should be provided where surrounding conditions are such that a supply of unfiltered clean air is unobtainable. In most industrial districts the pollution of the atmosphere necessitates the use of an air-washer or filter.

Obviating Noise in Plenum System

Special provision is necessary to minimise noise in all cases, except perhaps in factory premises. The fan should be carefully chosen with this in mind, and a slow-running rope-driven fan should be selected in preference to a direct-driven one, where the impeller wheel is mounted on the motor shaft. Flexible connections between the trunking and fan at the inlet and outlet should be provided. These can be of either leather or stout canvas. The fan and motor should also be mounted on anti-vibration bases of cork or similar material.

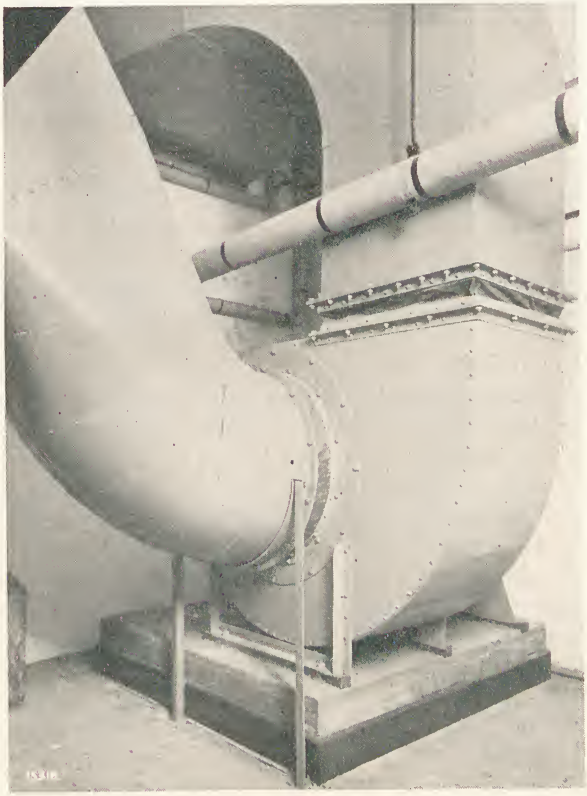


Fig. 2.—BLOWING DUCTWORK CONNECTED TO CENTRIFUGAL FAN WITH FLEXIBLE CONNECTIONS (*Airducts, Ltd.*)

Air Velocity

The velocity of the air through the ducts should not exceed 1,000 ft. per min. and the size of the air inlets should be based on a maximum velocity of 200 ft. per min. *Note :* As the air-inlet grilles are often of a decorative character, the clear area through them will frequently be found to be less than 50 per cent. of the total area. This must be taken into consideration when sizing the grilles.

The ductwork is usually of galvanised sheet steel, and should be of the following minimum thicknesses :—

For circular ducts—

				Up to 18 in.	diameter,	24	gauge
Over 18 in.	diameter and	,,	30 in.	,,		22	,,
,, 30 in.	,,	,,	,,	42 in.	,,	20	,,
,, 42 in.	,,	,,	,,	72 in.	,,	18	,,

For rectangular ducts—

		Up to 12 in.,	24	gauge
Over 12 in.	,,	18 in.	22	,,
,, 18 in.	,,	30 in.	20	,,
,, 30 in.	,,	48 in.	18	,,
,, 48 in.			16	,,

The heaters used are commonly of the gilled tube type and may be heated by water or steam. The steam-heated unit, because of the higher rate of heat transmission, is more compact than one of equal duty heated by water.

Hot Water

Heating by hot water is the most common form of central heating in use in this country. By its adoption a large building can be effectively heated from one boiler, with the consequent avoidance of the labour and dust inseparable from the individual heating of rooms by coal fires.

Low running costs and safety from fire are only two of the advantages which make worth while the initial cost of an installation. There is still a good deal of prejudice against this form of heating in private houses, largely the result of badly designed systems, which in the past were based on rule-of-thumb methods. With such aids as automatic temperature control, calculated heat requirements and scientific distribution of heating surface which the heating engineer now relies upon, the old causes for complaint have largely been removed.

Steam

The use of steam for heating is confined chiefly to buildings where steam is already available and required for other purposes. In factories, for instance, there is often sufficient exhaust steam available from process plant for the heating of the entire building. By the utilisation of this waste heat, considerable economy can be effected. Steam is also used indirectly for hot-water heating by the use of calorifiers.

In the vacuum system of steam heating, the pressure is kept below ordinary atmospheric pressure. The temperature of the radiating surface is therefore below that of steam at atmospheric pressure, viz. 212 degrees. One of the objections to steam heating, the stuffy smell usually associated with it, is thereby eliminated.

Gas Heating

Gas is used extensively in the modern building for both cooking and heating purposes. For private houses the familiar gas fire is a clean and convenient heating medium. The gas industry has been quick to take up the challenge of its powerful rival, electricity, with the result that the latest designs of gas-heating appliances are of pleasing appearance,

efficient and comparatively cheap to run. Special care has been taken in the design of the modern gas fire to ensure effective ventilation, which is so essential for satisfactory results.

The Gas Boiler for Central Heating

Increasing use has been made in recent years of the gas boiler for centralised hot-water heating installations. A high percentage of efficiency and the effectiveness of automatic control combined with the special cheap rates that are usually available for intending customers are sufficient to make its use an economical proposition. Other advantages are the absence of dust, saving of space in the boiler chamber, as no fuel store is necessary, and labour costs are, of course, negligible.

Electrical Heating

The present cost of electricity retards the rate of its extension to more general use for heating purposes, but it cannot be denied that it possesses advantages whch oil, gas or solid fuel cannot claim. For the occasional heating of a room such as a bedroom, the electric fire may be used with economy, as its effect is practically instantaneous, and there is no need to switch on except for a short time in the early morning and at bedtime. The advantages also of a portable electric fire are obvious when it is realised that there is no possibility of fumes or smoke permeating the atmosphere.

Thermal Storage System

Electric boilers have been successfully adopted for central-heating installations when used in conjunction with what is called a " Thermal Storage System." In this arrangement the current is switched on only during the " off peak " hours of the electric supply undertaking and the heat generated is stored for use at other times. The supply authorities are usually willing to sell current for these systems at especially low rates, in some instances as low as 0·2*d.* per unit. The fuel costs of an electrically heated thermal storage plant are thereby considerably lower than in a system using electricity at the ordinary charges. Moreover, savings can be made in the cost of building construction, as no chimney or fuel store is necessary. Labour charges are considerably reduced, as the plant is practically automatic, and the value of the cleanliness resulting from the absence of smoke, dust and ashes cannot be disregarded.

A typical arrangement of an electric thermal storage plant is shown in Fig. 3, and will be seen to consist essentially of a boiler, storage vessel, circulating pump and automatic mixing valve. The water in the storage vessel is heated up to a temperature often well over 200 degrees, and is fed to the heating system through the mixing valve in sufficient quantities to maintain the building at the required temperature.

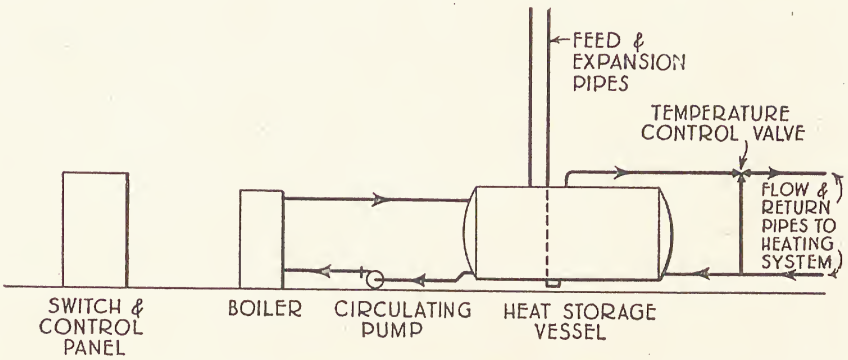


Fig. 3.—TYPICAL ARRANGEMENT OF AN ELECTRIC THERMAL STORAGE PLANT

This consists of a boiler, storage vessel, circulating pump and automatic mixing valve.

Radiant Heat

The radiation of heat is a continuous emission of that form of energy, in waves of varying length from all bodies at all temperatures, and follows the laws of light. Different surfaces maintained at the same temperature have varying powers of radiation. A surface that has a high radiating power has a correspondingly high capacity for the absorption of heat. A lamp-blacked surface has a high radiating power, as opposed to the poor radiating property of a polished surface. For instance, if the radiating power of a lamp-blacked surface is taken at 100, the relative figure for a polished copper surface is 11. Use is made of this fact in the construction of a vacuum flask, which comprises a double-walled glass vessel, with the space between the walls exhausted of air, and the surfaces of the walls silvered. The vacuum minimises conduction, and the mirrored surfaces reduce radiation to a minimum.

The heating effect of the column type of radiator is largely by convection rather than radiation, whereas with low-temperature flat surfaces employed in panel heating the percentage of radiation is greater than the convected heat.

Latent Heat

In order to change the state of a substance from solid to liquid and from liquid to gas, it is necessary to impart heat continuously to that substance until a temperature is reached where the solid begins rapidly to liquefy. The continued absorption of heat by the liquid raises its temperature to a point where rapid evaporation commences. If the liquid is water, we know that under atmospheric pressure the maximum temperature reached is 212° F.—boiling-point. Further absorption of heat does not increase the temperature, but is used in changing the state from liquid to vapour. By experiment, the amount of heat required to

convert 1 lb. of water at a temperature of 212° to steam at the same temperature and under the same conditions of pressure is 965·2 British Thermal Units (B.T.U.). The quantity varies with the pressure, and reference should be made to the steam tables found in most engineering reference books or to those published by Marks & Davis.

Specific Heat

The specific heat of a substance may be defined as the quantity of heat required to raise the temperature of unit mass of the substance through one degree. From experiments, it has been found that one substance will require a different quantity of heat than another to raise its temperature through the same range. This difference in thermal property is expressed by saying that the substances have different specific heats.

The specific heat of dry air, for example, at 60° F. is 0·239 B.T.U. per lb. and the weight of a cubic foot of dry air at the same temperature is 0·076 lb. Therefore, one B.T.U. (British Thermal Unit) will heat $\frac{1}{0{\cdot}239 \times 0{\cdot}076} = 55$ cubic feet of air through 1° F.

The following table gives the specific heats of various substances:—

Material.	*Specific Heat.*	*Material.*	*Specific Heat.*
Water	1·0	Mercury (70°–210°)	·033
Air (at constant pressure)	·239	Brickwork and Masonry about	·20
Steam (at 212° F.)	·43	Building Stone	·20
Iron (70°–210°)	·12	Glass	·195
Steel (70°–210°)	·123	Marble	·21
Cast iron (70°–210°)	·13	Granite	·19
Copper (70°–210°)	·094	Asbestos	·20
Brass (70°–210°)	·094		

Measurement of Heat

The quantity of heat possessed by a body depends upon several factors of which temperature is but one. It is evident that, since the time taken to raise the temperature of a quart of water from, say, 50° F. to boiling-point will be twice as long as that taken to heat a pint of water through the same range of temperatures, provided the same gas jet is used, then twice the amount of heat is required. A piece of wire held in a flame will rapidly come to a red heat, although obviously only a small quantity of heat has been absorbed. In order, therefore, to measure heat, it is necessary to adopt a unit as a standard. The standard heat unit generally used in England is the British Thermal Unit (B.T.U. or B.Th.U.), and is the quantity of heat necessary to raise the temperature of 1 lb. of pure water at 39·1° F. through 1° F.

Conduction

The transference of heat from one part of a substance by conduction is very easily illustrated by the simple experiment of putting a poker

into the fire and observing how quickly the handle becomes hot, even though it is screened from the direct rays of the fire. It is therefore evident that if the temperature of one part of a body is raised above that of the other parts, heat will be passed on to them. Different substances vary in their conductivities. Iron, for example, may be considered a good conductor of heat, but asbestos a bad one. Materials that are considered bad conductors are accordingly selected for use as heat insulators.

The proper insulation of the boilers and distributing pipes in any heat-raising system is an important factor for the maintenance of a high degree of efficiency.

The table below gives the insulating properties of various materials commonly used by the heating engineer.

Substance.	*B.T.U. per sq. ft. per hour per inch Thickness for 1° F. Temperature Difference between the Faces.*
Slag Wool	·38
Asbestos	1·10
Powdered Cork	·29
Granulated Cork	·35
Cork Slab	·38
Hair Felt	·26
Kieselguhr (loose)	·46
Sawdust	·49
Magnesia Asbestos Compo	·44
Wool	·32
Air (at rest)	·15
Cotton Waste	·41

Convection

Heat that is conveyed from place to place by the actual motion of the heated body causes its transference by convection.

Water and air transfer heat almost entirely by convection rather than by conduction.

In a hot-water heating installation, where pipes and radiators are used, the distribution of heat is to a large extent by convection. The water in the boiler on being heated expands and its density becomes less. Under the action of gravity the heated water moves upwards, and is replaced by colder water, which in turn is heated, and so a movement is set up through the pipes of the installation. The pipes and radiators become heated by the water and transfer heat to the surrounding air, which is also set in motion in the same way and conveys heat to the occupants and objects in the room.

CENTRAL HEATING BY HOT WATER

Low- and High-pressure Systems

The essential difference between low- and high-pressure hot-water heating systems is, that in the low-pressure system there is always an

open expansion pipe, whereas the high-pressure system is a closed one with very little provision for the expansion of water.

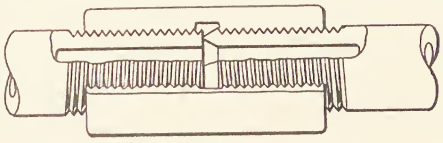


Fig. 4.—SHOWING THE ARRANGEMENT OF JOINTING FOR HIGH-PRESSURE SYSTEMS

The pressure in a low-pressure system is governed by the water level in the feed tank. If we consider a filled system where the tank is 30 ft. above the level of the boiler, the pressure at the boiler will be approximately 13 lb. per sq. in. above ordinary atmospheric pressure. Boiling-point at this pressure is 245·7° F. In the pipes and radiators situated on the upper floors of the building the pressure will naturally be less and the temperature correspondingly lower.

The usual maximum temperature allowed in the design of a low-temperature apparatus is 180° F.

The pressure or "static head" produced by a column of water is equivalent to 0·433 lb. per sq. in. for every foot in height.

The following table gives the corresponding pressure and boiling-points of water for various heights of water column:—

Height of Column. Feet.	*Pressure in pounds per square inch.*	*Boiling-point at Bottom of Column.* ° F.
2	0·866	214·9
4	1·732	217·6
6	2·598	220·3
8	3·464	222·8
10	4·330	225·3
15	6·500	231·0
20	8·660	236·2
25	10·830	241·2
30	12·990	245·7
35	15·160	249·9
40	17·320	253·8
45	19·490	257·7
50	21·650	261·3

In the high-pressure system, pipes of about 1-in. bore are used, some of which, formed into a coil, are set in a furnace and connected to the pipes distributed in the building to be heated. The system is filled under pressure and sealed, leaving only a small space in the expansion chamber. When heat is applied, a high temperature is obtained and a rapid circulation of the water in the system is set up. The pipe coil forming the boiler is a continuous one, without joints. The joints in the pipe lines are formed by using right- and left-hand threaded sockets on correspondingly threaded pipes. The ends of the pipes are trued and one is chamfered, so that when the socket is pulled round, the ends of the pipes are drawn together. Sufficient force should be used to cause the chamfered edge of one to "bite" into the flat end of the other. No jointing material is necessary (Fig. 4).

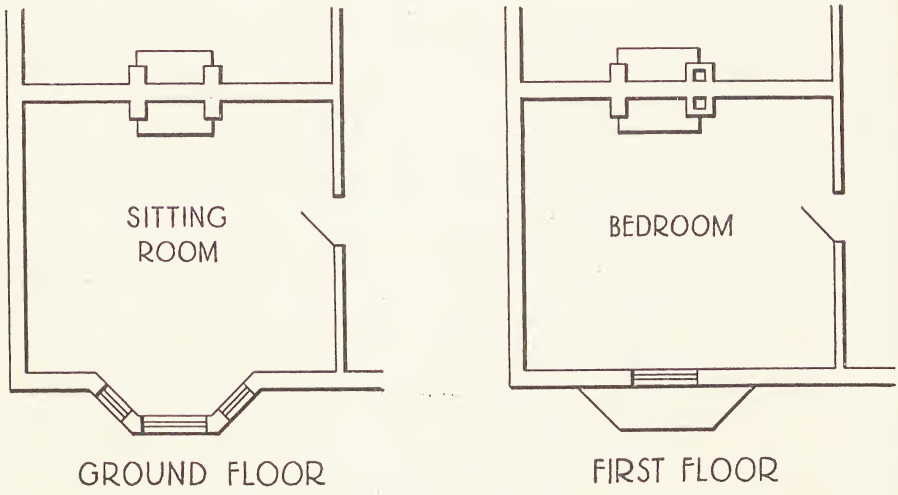


Fig. 5.—TWO ROOMS IN A TYPICAL TWO-STOREY BUILDING

The method of calculating the heating for two rooms such as these is fully described in this article.

The high temperature of the pipes gives an unpleasant quality of heat and the system is now practically obsolete.

Heat Losses

The computation of heat losses from a building is one of the first calculations necessary in the design of a heating system. It is useful to prepare a specially ruled form on which an analysis can be made of the heat requirements. The form may be ruled in columns with headings for :

(1) The names of the rooms.
(2) Cubic capacity in cu. ft., i.e. length × breadth × height.
(3) B.T.U. required for warming the air.
(4) Heat loss through windows and other glass.
(5) Heat loss through walls.
(6) Heat loss through roofs.
(7) Heat loss through floors.
(8) Totals of (3) to (7).
(9) Total heat loss, including added percentage for exposed condition of room.

The same form may have additional columns for the amount of piping and radiator surface allocated to each room as found necessary from column 9.

Reference should be made to published coefficients of transmission for the various exposed surfaces, and these can be found in the catalogues of most radiator manufacturers. On page 14 will be found a list giving the coefficients for materials of common occurrence.

If the building is an existing one and there are no plans available, the engineer must take sufficient particulars during his survey of the building so that reliable data will be at hand in the drawing office. These particulars should include, in addition to the sizes of the rooms and the general layout of the building, areas of all exposed glass, thickness and construction of walls, type of roof or ceiling, type of floor and orientation of the building.

If plans have already been prepared by an architect, there is usually sufficient information given regarding the construction of the building for the calculation of the total heat losses.

Consider, for example, the calculations for the heating of two rooms of a two-storey building as in Fig. 5, one on the ground floor and the other immediately over on the first floor.

Sitting-room. Contents 16 × 14 × 10 = 2,240 cu. ft. Internal Temperature, 60°; outside, 32°. Ventilation Allowance, 2 Air changes per hour.

	B.T.U.
Air, 2,240 × 2 × 0·019 × 28° temp. rise	2,343
Glass, 72 sq. ft. × 1·05 × 28°	2,117
Wall (9-in. brick, plastered), 228 sq. ft. × ·33 × 28°	2,107
Roof (not exposed, heated room over)	—
Floor (boarded on joists), 224 sq. ft. × ·05 × 28°	314
	6,881
Add 10 per cent. N. exposure	688
Total	7,569

Bedroom. Contents 16 × 14 × 8 = 1,792 cu. ft. Internal Temperature required, 55°; outside, 32°. Ventilation Allowance, 2 Air changes per hour.

	B.T.U.
Air, 1,792 × 2 × 0·019 × 23° temp. rise	1,566
Glass, 30 sq. ft. × 1·05 × 23°	725
Wall (as sitting-room), 210 sq. ft. × ·33 × 23°	1,594
Roof (lath and plastered ceiling with tiled roof boarded on one side of rafters), 224 sq. ft. × 0·24 × 23°	1,236
Floor (not exposed, heated room below)	—
	5,121
Add 10 per cent. N. exposure	512
Total	5,633

The labour involved in multiplying the various factors and calculating the heat losses generally will be greatly reduced by the use of the slide-rule.

In the following table, the co-efficients given are for the more common type of building; they are based on "still air" conditions and for buildings that are continuously heated. It is recommended that not less than 25 per cent. be added to the figures for buildings heated for short periods and 10 per cent. for north or east exposures. For more comprehensive lists the reader is referred to the data given in the catalogues of most radiator manufacturers and which will be found quite reliable.

Fig. 6.—SHOWING THE DIFFERENCE IN HEATING EFFECT FROM PIPES FIXED HORIZONTALLY AND VERTICALLY

Glass	*B.T.U. per sq. ft. per ° F. Difference between Inside and Outside Temperatures.*
Single Windows	1·05
Double Windows	·52
Plate Glass	·74
Single Skylight	1·15
Double Skylight	·55

Walls	*Thickness. Inches.*	
Brick, solid, plastered inside	9	·33
,, ,, ,, ,,	14	·25
,, ,, ,, ,,	18	·22
Brick, with air space, plastered inside	9	·29
,, ,, ,, ,, ,,	14	·23
,, ,, ,, ,, ,,	18	·2
Limestone	12	·55
,,	18	·45
,,	24	·38
Floors		
Boarded on joists, with airspace and concrete raft under		·05
Wood Block Floor on concrete		·25
Roofs and Ceilings		
Open tiled roof with rafters boarded on one side		·35
Lath and plaster ceiling and roof as above		·24
Open tiled roof with rafters boarded both sides		·18
Lath and plaster ceiling and roof as above		·15
Flat reinforced concrete roof laid with asphalt, 6 in. thick		·28
,, ,, ,, ,, ,, 9 in. thick		·25

Ventilation Allowances

This is a matter for the careful discrimination of the engineer, as it is obvious that the size, number of doors and windows, and the use to which the room is put will affect the rate of air change. The following schedule will serve as a guide to the allowances usually made for various types of buildings :—

	Internal Temp.	*Air Changes per hour.*
Living-rooms	60° F.	2
Bedrooms and Passages	55	2
Entrance Halls	60	4
Office Buildings	60	2
Churches, Large	55	1
,, Small	55	1½
Schools, Classrooms	62	4
Hospitals, Wards	65	3–4
,, Operating Theatres	75	6
,, Staff Rooms	60	2

Note.—In systems where radiant heating is used, the allowances made for ventilation in the total heat load calculations can be considerably reduced as the heating by convection is much lower than in the ordinary radiator system.

Heat Transmission

The amount of heat given off by the heating surface varies according to the temperature difference of the pipes and radiators and the surrounding air; the exposed or enclosed condition of the heating surface; the type of radiator and other factors which may tend to assist or obstruct the distribution of heat. The difference in heating effect is very noticeable if the results from pipes fixed horizontally and vertically are compared, as shown in Fig. 6.

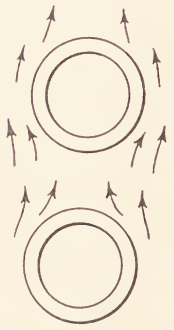


Fig. 7.—SHOWING HEAT TRANSMISSION FROM TWO HORIZONTAL PIPES PLACED ONE ABOVE THE OTHER

The heated air in the immediate vicinity of the vertical pipe rises and keeps close to the pipe, thereby reducing the temperature difference and lowering the rate of transmission. On the other hand, the air warmed by the horizontal pipe rises and leaves the pipe immediately, to be replaced by cooler air. The transmission from a group of pipes is less per square foot than from a single pipe. Consider a case where two horizontal pipes are placed one above the other (Fig. 7); the heated air from the lower pipe rises and envelops the pipe immediately above. The temperature difference between the upper pipe and the surrounding air is, therefore, lower and the heat transferred correspondingly less.

Heat Transmission in B.T.U. per hour per lineal foot from Iron Pipes.

Diameter of Pipe.	*Temperature Difference ° F.*											
	60°	70°	80°	90°	95°	100°	105°	110°	115°	120°	125°	130°
½ in.	29	35	42	49	52	56	60	63	67	71	75	79
¾ in.	36	44	52	61	65	70	75	79	84	89	94	98
1 in.	41	50	60	70	75	80	85	90	96	101	107	112
1¼ in.	50	61	73	85	91	98	105	111	118	124	131	138
1½ in.	57	69	82	96	106	110	117	124	132	140	147	155
2 in.	67	82	97	113	121	130	139	147	157	165	174	183
2½ in.	79	97	115	134	144	154	164	174	185	195	206	217
3 in.	97	118	141	164	176	188	200	213	226	238	252	265
4 in.	120	146	174	202	217	232	247	262	280	294	310	326
5 in.	145	177	210	246	264	282	300	319	340	358	378	397
6 in.	170	207	247	288	308	330	352	373	398	418	442	465

The velocity of the air over the heating surface affects the rate of transmission, in that, as the velocity is increased, the rate of transmission is increased. With certain forms of heating surface, experiments have shown that the heat transmission is doubled with a fourfold increase in the air velocity.

The table on page 15 gives the transmission in B.T.U. per lineal foot for horizontal iron pipes freely exposed and subject to natural conditions of convection. For pipes fixed overhead, not more than 80 per cent. should be taken of the figures quoted and for vertical pipes 50 per cent.

It will be noted that the figures quoted do not vary directly with the variations in the temperature difference. It has been found by investigation that for practical purposes the transmission, for temperature differences of, say, T_1 and T_2, will vary as $T_1^{1.3}$ and $T_2^{1.3}$; thus, if a 2-in. pipe at 160° surrounded with air at 60°, i.e. 100° temperature difference, transmits 130 B.T.U. per lineal foot at 130° and the same air temperature, viz. 60°, i.e. 70° temperature difference, it will transmit

$$\begin{aligned} & 100^{1.3} : \quad 70^{1.3} :: \quad 130 \quad : \quad K \\ = \; & 398 \quad : \quad 250 \quad :: \quad 130 \quad : \quad K \end{aligned}$$

$$\text{Then } K = \frac{130 \times 250}{398} = 82 \text{ B.T.U./lin. ft.}$$

QUESTIONS AND ANSWERS

What is meant by the Plenum System of Ventilation ?

A " Plenum System " is one where warm air is blown into the building at a larger rate than the ventilating system removes it, so that a slight pressure is created. Air leakage through doors and passages tends, therefore, to be in an outward direction.

What are the main elements of the Plenum System ?

A fan or blower, air-heater (air-washer and air-filter where conditions require), and distributing ductwork.

Describe briefly the Thermal Storage System.

The Thermal Storage System consists essentially of a boiler, storage vessel, circulating pump and automatic mixing valve. The water in the storage vessel is heated up to a temperature often well over 200° and is fed to the heating system through the mixing valve in sufficient quantities to maintain the building at the required temperature. The current is switched on only during the " off peak " hours of the electric supply undertaking, and the heat generated is stored for use at other times.

What is the chief difference between the Low- and High-pressure Hot-water Heating Systems ?

In the low-pressure system there is always an open expansion pipe. The high-pressure system is a closed one, with very little provision for the expansion of water.

THE DRAINAGE OF BUILDINGS

IMPORTANT CONSIDERATIONS IN THE PREPARATION OF A SCHEME

THE drainage of buildings is a matter which must vary in accordance with the requirements and conditions of each case. The requirements may consist of the safe and expeditious removal of waste waters and rain water by means of drains laid with sufficient fall to the public sewer. The points from which run the drains, as distinguished from soil pipes, waste pipes and rain-water pipes, which are above ground, may happen to be in convenient positions outside the building. The ground in which the pipes have to be laid may be of a dry, self-supporting character and the public sewer may be of the combined type into which both rain water and sewage may be taken. These are, perhaps, the normal conditions under which a very large proportion of house drains have to be laid ; but there are other conditions which have to be encountered, and those who have to deal with such work must be prepared for problems and difficulties.

DIFFICULTIES MET IN PRACTICE

Such conditions as the following are not uncommon. The site upon which the house is built may be wet, and efficient land drainage may be required. The property may be such that drains have to be carried under the house in order to deal with back premises or with soil pipes, rain-water pipes and sealed gullies situated within the building. The fall between the house site and the sewer may be insufficient to make possible drains laid with a self-cleansing gradient and the levels may even be such that pumping is necessary. It may be necessary to lay a double system of drains, one set for sewage and the other for rain water. The drainage of basements may involve great difficulties, while it is possible that the ground through which the drains have to be laid is wet and unstable. There may also be dangers of back-flooding from overcharged sewers.

MAIN PRINCIPLES

For the reasons given it is impossible to say what may or what may not be needed in the design of any drainage scheme until all conditions are known. On the other hand there are certain main principles which apply to all work.

All drainage work must be absolutely sound ; it must be water-tight

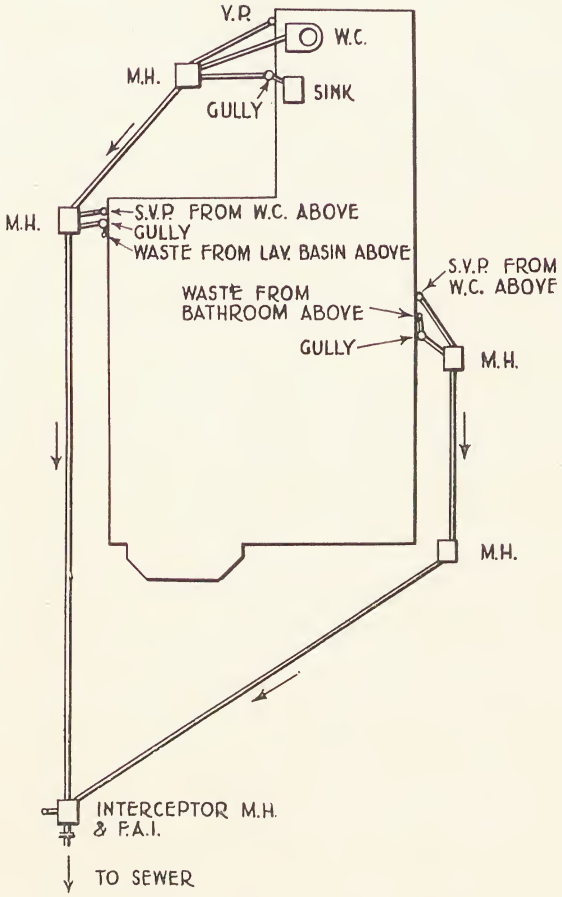


Fig. 1.—EXAMPLE OF AN EXTENSIVE DRAINAGE SYSTEM

This is required because of the irregular arrangement of the sanitary fittings.

and air-tight. For this reason all drains and manholes must rest upon sound foundations so that leakages and cracks due to settlement may not occur. There must be no places where solid matter or liquid sewage can lodge.

Accessibility

Every part of the drainage system should be accessible for cleaning. The drains must be so arranged and of such a character that they cannot be injured from above or crushed by the weight of any load coming upon them from traffic or from structural work, such as in the case of a pipe passing through or under a house wall. It is also necessary that all water-sealed traps connected to the drain shall be so arranged that they are not likely to be unsealed by evaporation.

Ventilation

Further, the whole system should be so arranged that there may be no undue air pressure or vacuum formation such as is likely to unseal the traps. As an ideal, air should circulate freely throughout the system. Finally, all points where free ventilation from the drains may occur, such as vent pipes, must be arranged in places where the outlet of drain air can create no nuisance and do no harm.

PLANNING OF HOUSE DRAINS

The planning and setting out of a drainage system is a matter which affects the cost of the work materially. Buildings are of many kinds.

In the modern building, if it is well planned, the sanitary fittings are so arranged that the drainage may be gathered at one or two positions from which a main drain can be carried, as shown in Fig. 2. All W.C.s, for example, are grouped on different floors in one part of the building; sinks and baths are similarly arranged, with the result that there is economy in the whole system. On the other hand there are very many of the older buildings in which the sanitary fittings have been arranged from time to time in many different places, with the result that the house is necessarily surrounded with gullies, soil pipes, drains, and manholes, requiring a system of drains difficult to design and expensive to construct. See Figs. 1 and 2.

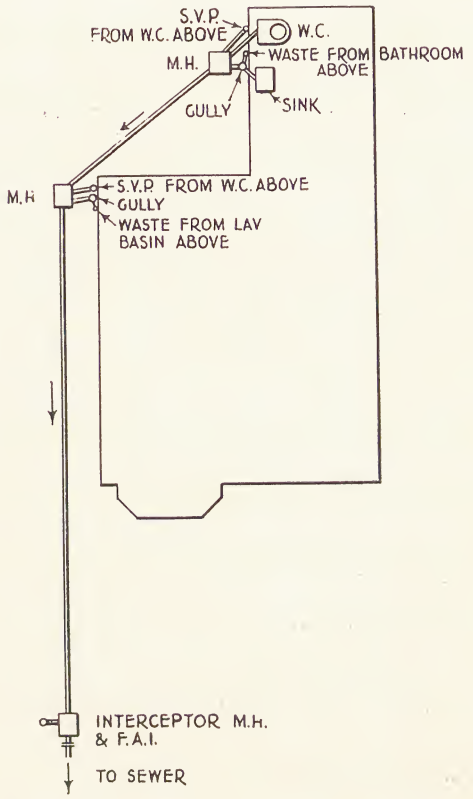


Fig. 2.—TYPICAL PLAN FOR HOUSE DRAINAGE SYSTEM

The sanitary fittings are so arranged that the drainage may be gathered at one or two positions from which a main drain can be carried.

In addition to the difficulties produced by bad arrangement of sanitary fittings, there is sometimes a great deal of unnecessary work involved in dealing with the rain water. A very little consideration in the arrangement of gutters and down-pipes will often save considerable work and expense. For instance, in a combined system it is quite unnecessary to install a special rain gully at the foot of a down-pipe if the rain water can be conveyed to a gully receiving waste from a sink or bath (Fig. 3).

Avoid Multiplication of Down-pipes

The multiplication of down-pipes is to be avoided because it is necessary to take each down-pipe into a gully, and this means not only the expense of supplying and fixing a gully, but the laying of a drain from the gully and the making of a connection to a manhole and possibly the construction of a special manhole. By careful planning of the work great economies and better results can be effected (Figs. 4 and 5).

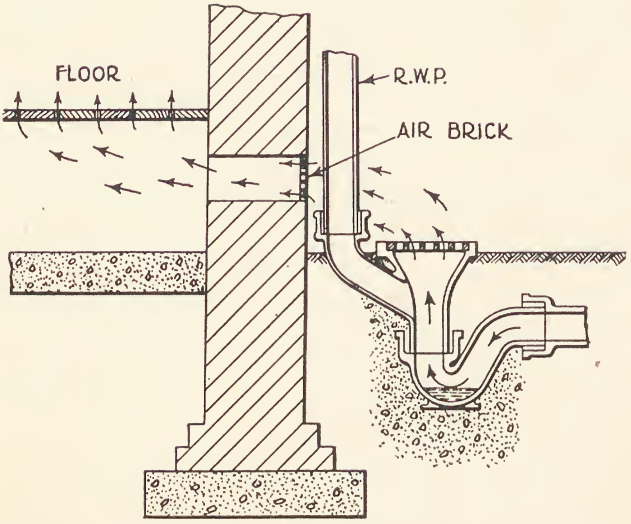


Fig. 2A.—IT IS NECESSARY TO REMEMBER THAT A TRAP WHICH RECEIVES RAIN WATER ONLY MAY BECOME UNSEALED IN DRY WEATHER

In the diagram above, the seal of the gully has evaporated, allowing foul air to pass into the house.

THREE KINDS OF DRAINAGE MAY BE REQUIRED

The drainage of a building may be considered under three headings :—

(1) The removal of water held in the ground causing a site to be damp and unhealthy. If the ground is waterlogged such drainage will be necessary. If it is dry, drainage of the subsoil is not required.

(2) The removal of rain water including surface water.

(3) The removal of sewage and waste waters.

Subsoil Drainage

If the site upon which the house is to be built is waterlogged it is possible to lay a system of land drains which will carry the water away and leave the site dry. If the site is situated above the level of the ordinary water-course draining away the surface water of the district, it may be a simple matter to drain the land water away by gravitation.

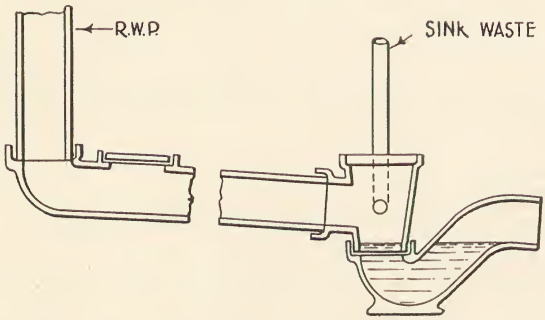


Fig. 3.—IN A COMBINED SYSTEM IT IS UNNECESSARY TO INSTALL A GULLY AT THE FOOT OF A DOWN-PIPE IF THE RAIN WATER CAN BE CONVEYED TO A GULLY RECEIVING WASTE FROM A SINK OR BATH

Land Drains

Open-jointed agricultural drain pipes can be laid to gather the land water, with a main drain to carry it away. The depth at which the pipes

must be laid and the distance apart of the lines of drain are matters which are dependent upon the character of the soil.

While a single pipe may be sufficient to drain the water away from a pocket of open gravel (Fig. 6) it might be necessary to lay lines of pipes two or three feet apart over the whole site in material which did not part with water so readily (Fig. 7). In laying such drains it is most important that the levels should be carefully fixed and that the pipes should be laid carefully so that there may be no back-falls ; on the other hand a very slight gradient is sufficient because the pipes will carry clean water without any solid matter and so will not be subject to such stoppage as might occur in a sewage drain.

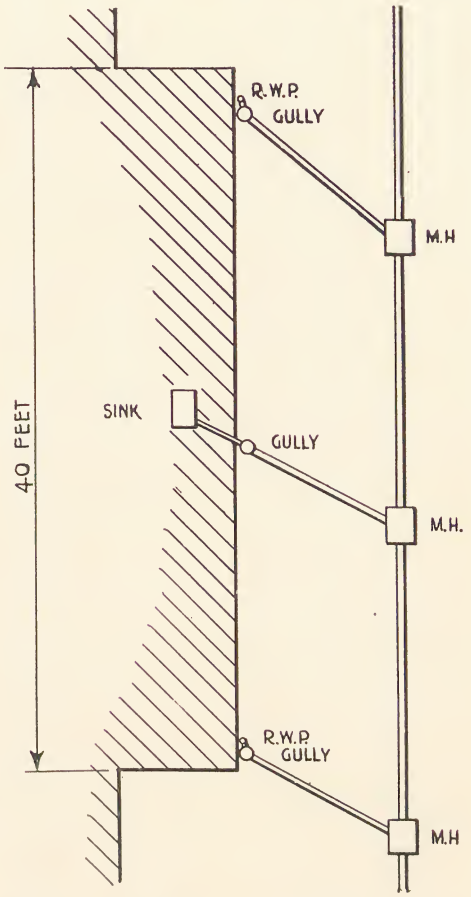


Fig. 4.—DIAGRAM SHOWING UNNECESSARY NUMBER OF RAIN-WATER DOWN-PIPES, GULLIES, BRANCH DRAINS, AND MANHOLES

Trenches

In laying these land drains the trenches must be carefully prepared. Level pegs should be driven at 10-ft. intervals and these should be carefully checked before any pipes are laid (Fig. 8). It is well to surround the pipes with 6 in. of clean gravel. The ends of the pipes should be about $\frac{1}{8}$ in. apart (Fig. 9).

Outfall

The system of land drains is then connected to one main drain which is carried to a suitable outfall situated at such a level that there is no risk of a back-flow of water into the system.

Pipe Sizes

The sizes of pipes will depend upon the volume of water to be carried away, and as this water can flow continuously it is improbable that

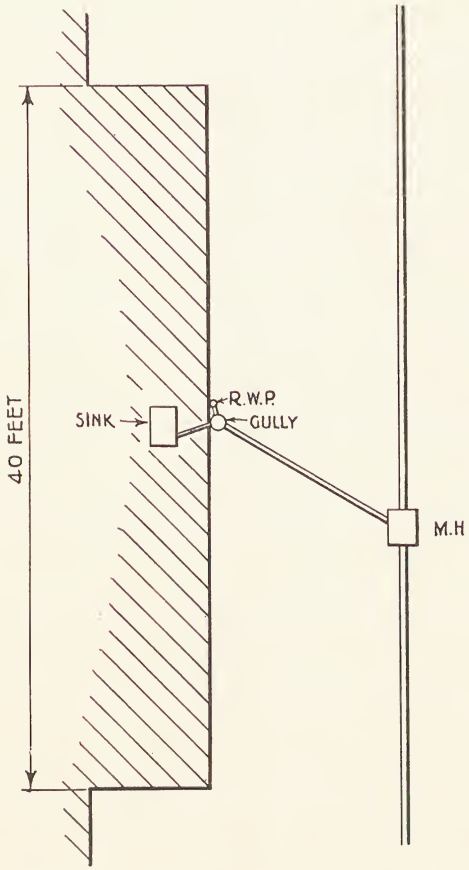


Fig. 5.—ARRANGEMENT FOR DOWN-PIPES

In this case only a single rain-water down-pipe is used. If the construction of the building calls for rain-water pipes, then an overseal drain with rain-water shoe at foot should be used.

any pipes of large size will be required in ordinary cases. For guidance it may be useful to know that a 3-in. pipe laid at a gradient of 1 in 100 can deliver 40 gallons a minute and that a 4-in. drain laid at the same gradient will deliver about 90 gallons a minute. Fig. 10 gives an example of subsoil drainage.

The Drainage Pump

It may well happen that there is no suitable water-course into which the land water can be drained by gravitation. In that case it is customary to connect the system of subsoil drains to an underground pit whence it is lifted by means of an automatic pump which is set in action by the rise of the level of the water in the pit (Fig. 11). For instance, an electrically driven pump may be used and the current switched on and off by the rise and fall of a float.

Land Drainage and House Drainage Must be Separate

It is extremely important to see that there may be no possible connection between the subsoil drains and the house drains. If any such connection is made to a manhole or drain, the drain air may be carried into the house and any back-flow due to drain stoppage will fill the subsoil drains with sewage. It is also extremely undesirable that any soakage pit or surface-water gully either inside or outside the house should be connected to the subsoil drains, neither should rain-water pipes be connected to them for the reason that there is always a possibility of dirty water and washings entering the drains from such connections and causing the subsoil drains to become foul and possibly inoperative through clogging. The land drainage system should therefore be kept absolutely separate.

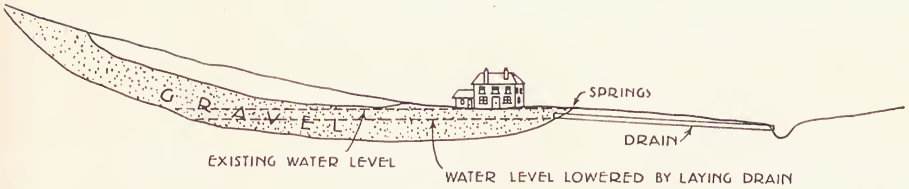


Fig. 6.—SHOWING HOW A SINGLE PIPE MAY BE SUFFICIENT TO DRAIN THE WATER AWAY FROM A POCKET OF OPEN GRAVEL

RAIN WATER AND SURFACE WATER DRAINAGE

In some districts, where the sewers receive rain water and sewage, it is customary to lay a combined system of house drains, that is to say the water from surface gullies and from rain-water gullies is carried away in pipes which are connected to the sewage drains. Elsewhere there may be two systems of sewers, one taking rain water and surface water and one taking sewage. Under such conditions two separate systems of house drains are required, one for rain and surface water and the other for sewage.

Where a combined system of drains is laid it is necessary to remember that the trap of any gully which receives rain water only may become unsealed through evaporation in dry weather (Fig. 2A). For this reason it is good practice to connect rain-water down-pipes to gullies which receive bath and similar wastes, because the traps of these gullies will be kept sealed by the constant flushes entering them. When there is no gully of this kind near the rain-water down-pipe it is often possible to carry a drain from the down-pipe to the gully as shown in Fig. 3.

As the rain-water drain is clean there is no object in placing a trapped gully at the foot of the rain-water down-pipes, and a rain-water shoe, as shown in Figs. 3 and 12, can be used instead of a gully. It will be observed that the drain may be cleared from this shoe as it is in the nature of an inspection eye.

A Practice Open to Criticism

In the majority of house drainage systems certain rain-water down-pipes are connected to separate trapped gullies which are connected to the sewage drain manholes. The arrangement is open to criticism for

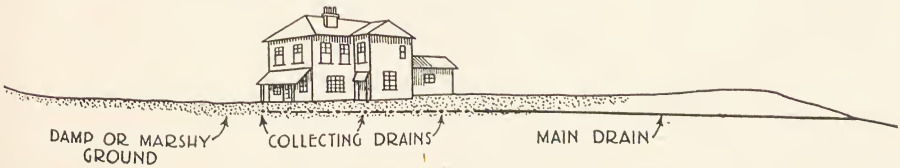


Fig. 7.—IN THE CASE OF A SOIL WHICH DOES NOT PART WITH WATER SO READILY AS GRAVEL IT MAY BE NECESSARY TO LAY LINES OF PIPES TWO OR THREE FEET APART OVER THE WHOLE SITE

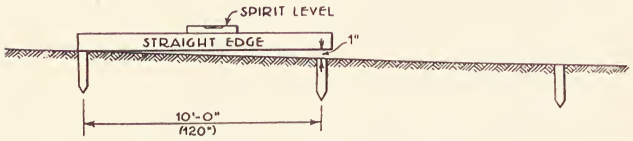


Fig. 8.—When preparing a trench for a land drain a drop of 1 inch in every 10 feet should be allowed

the reasons stated above. Rain-water drains can be carried from the various down-pipes, and the main rain-water drain into which they discharge may be connected to a gully receiving wastes as shown in Figs. 13 and 14, or may be trapped off separately at a manhole as shown in Fig. 15.

Provision for Cleaning

It should be observed that a rain-water branch drain of moderate length coming from a shoe may be connected with safety to a main rain-water drain without any manhole at the junction because it can be cleaned by means of a rod and brush from the shoe (Fig. 12). On the other hand, where a long branch occurs, joining a main rain-water drain, a manhole or other facilities must be provided as it is necessary that the drain should be accessible for cleaning in all parts.

Fig. 9.—The ends of the drain pipes should be about $\frac{1}{8}$ inch apart

In Country Districts

In the country, rain-water drains are sometimes connected to an underground tank in which the water is stored for household purposes. In such cases it is most important to note that no gullies into which

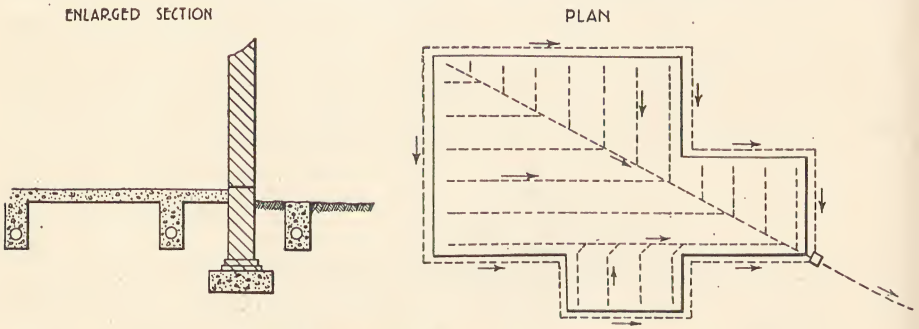


Fig. 10.—Typical example of subsoil drainage

The subsoil drains in the trenches are surrounded with gravel and the trenches are filled with gravel.

surface water runs should be connected, and that the rain-water shoes should be provided with covers instead of open grids as shown in Fig. 3. Unless this is done there will be every probability of water of an undesirable quality entering the rain-water tank. Further, it is very important that the tank overflow should be carried to a safe outlet. It must not be connected to the drains because in that case a back-flow of sewage into the tank becomes possible.

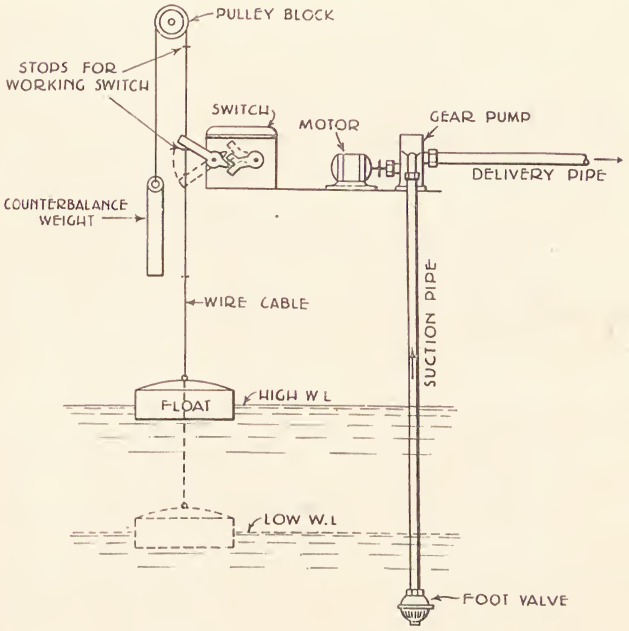


Fig. 11.—DRAINAGE PUMP

Where there is no suitable water-course into which the land can be drained it is usual to connect the system of subsoil drains to an underground pit whence it is lifted by means of an automatic pump.

The Importance of Rain-water Drains

Rain-water drains should be watertight and, with the exceptions mentioned, should be arranged and constructed in the same manner as the sewage drains later described. It is common practice to regard rain-water drains as being of secondary importance, and the by-laws do not always emphasise their proper importance. Defective rain-water drains and neglect of proper planning and arrangement can cause much trouble, such as dampness of basements, saturation of the house foundations, objectionable outlets of drain ventilation round the house, pollution of stored rain water and unnecessary expense in maintenance and probable relaying.

SEWAGE DRAINS

Careful planning and consideration of levels is the first necessity in drainage work. The planning is often of such a character that a great deal of needless expense is incurred on work which would not be required if common sense had been exercised.

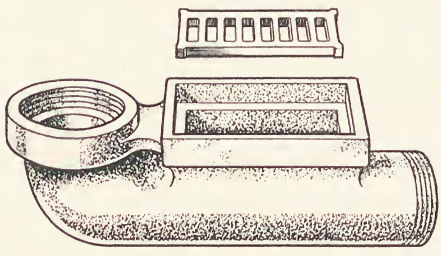


Fig. 12.—RAIN-WATER SHOE

The drain can be cleared from this shoe, as it is in the nature of an inspection eye.

Preliminary Notes

For instance, gullies are often included which might have been omitted by a slight extension of waste pipes. Where an unnecessary gully is included in the design it means that a branch drain must also be provided with a manhole connection. Hidden junctions are not uncommon but they are wrong. They are very objectionable and should not occur.

Things to be Avoided

In Fig. 16 a common arrangement is shown which is bad for several reasons, which should be carefully noted.

The long branches might be avoided, the rain-water gulley and branch drain connected to the sewage drain might also be avoided, the long branches cannot receive proper ventilation, and the total length of the drain is much greater than it need be. Reference to the section, Fig. 16, will show that the gully at the head of the drain being of unnecessary depth causes the whole length of the drain beyond to be deepened, with corresponding unnecessary expense.

A Better Arrangement

In Fig. 17 a better and more economical arrangement is shown. It will be observed that the following improvements have been effected :—

(1) By altering the position of the sink waste pipe—a very simple matter—a certain length of drain above manhole No. 1 is done away with.

(2) The hidden bend and the hidden junction, both of which are objectionable, are avoided.

(3) As gully A can be placed in a better position the gully B becomes unnecessary and can be omitted, and the rain-water down-pipe can be made to discharge into gully A.

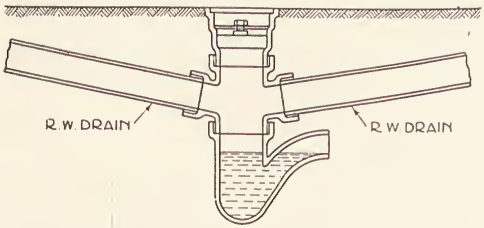


Fig. 13.—RAIN-WATER DRAIN CONNECTED TO A GULLY RECEIVING WASTES

(4) The branch drain and hidden junction connected to gully B are done away with.

(5) The danger of drains ventilating at an improper point is overcome because there is now no possibility of the unsealing of the gully trap by evaporation as the rain-water pipe is made to discharge into a sink gully.

(6) Whereas in the bad arrangement shown in Fig. 16 the drain above manhole 1 was unventilated, in the improved scheme there is an air current through the whole system sufficient to ventilate the very short branches entering manholes Nos. 1 and 2.

(7) By placing manhole 2 close to gully C another long unventilated branch drain is avoided.

(8) As this manhole 2 is nearer the head of the drain where the pipe is at a shallow depth, it will be of small size and the cost of its construction will be correspondingly less.

(9) By connecting the rain-water down-pipe to gully C, gully D and its branch drain, hidden junction and possibilities of trap evaporation is avoided.

(10) From the section, Fig. 16, it will be seen that the sink gully A, at the head of the drain, is set at a deeper level than is necessary. On the section in Fig. 17 the gully is kept at a higher level, and the whole of the drain beyond is shallower in consequence and is therefore less expensive to construct.

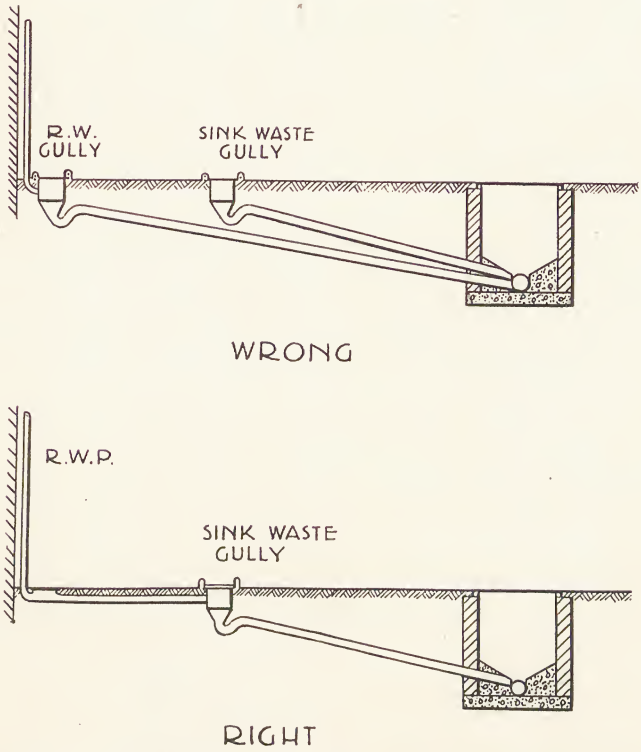


Fig. 14.—ANOTHER EXAMPLE OF A RAIN-WATER DRAIN CONNECTED TO A GULLY RECEIVING WASTE

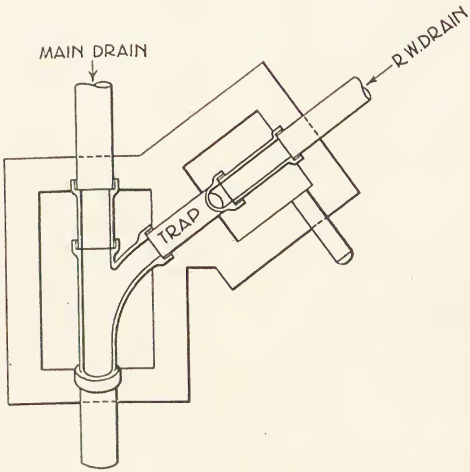


Fig. 15.—ARRANGEMENT FOR RAIN WATER TRAPPED OFF SEPARATELY AT A MANHOLE

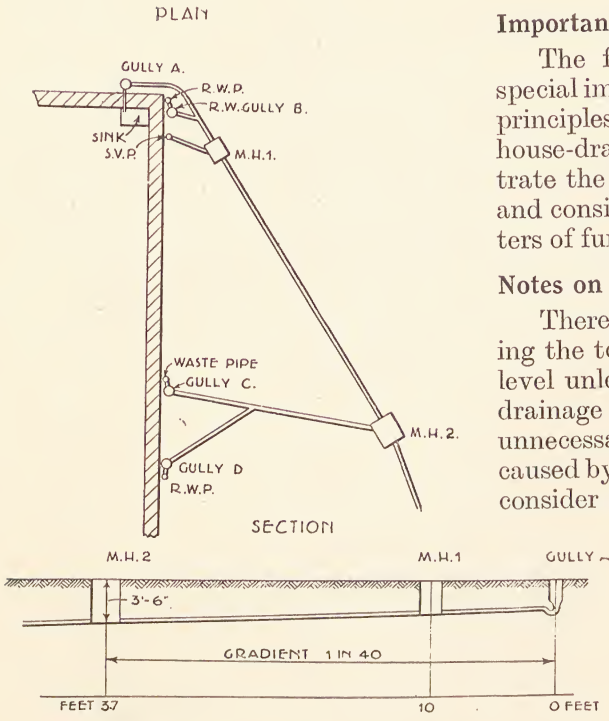


Fig. 16.—A BAD ARRANGEMENT OF SEWAGE DRAINS

Importance of Careful Planning

The foregoing remarks are of special importance because the same principles apply throughout any house-drainage scheme; they illustrate the fact that careful planning and consideration of levels are matters of fundamental importance.

Notes on Gullies

There is no advantage in keeping the top of a gully below ground level unless it is to be used for the drainage of surface water, and much unnecessary work and expense are caused by doing so. It is necessary to consider carefully the purpose for which each gully is required. If it has to take surface water the grid must be slightly below the surface of the yard or area which it has to drain, but if the gully is required in order to receive sink, bath, or lavatory wastes, or the discharge from down-pipes, and does not have to take surface water, its level is a matter which can be arranged to suit the special requirements of the case within wide limits. There are examples of gullies taking wastes from sinks, etc., which are fixed many feet above ground level with heavy cast-iron drain-pipe connections carried to the underground drains, and in cases where the fall is limited it may sometimes be found to be advantageous to keep the gully at a high level

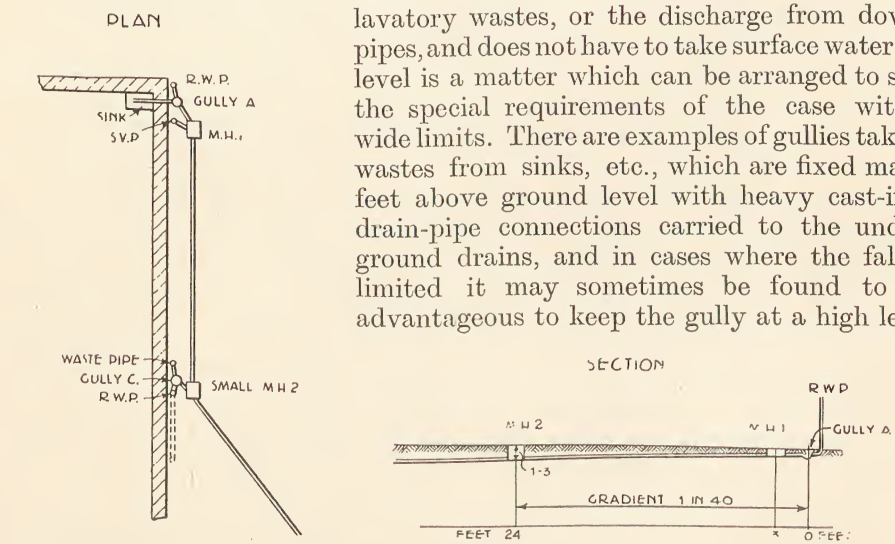


Fig. 17.—A BETTER AND MORE ECONOMICAL ARRANGEMENT FOR SEWAGE DRAINS

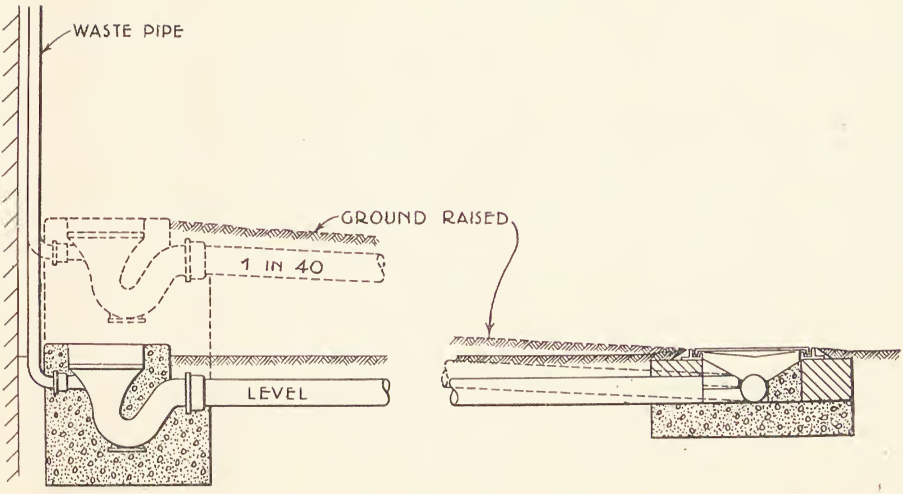


Fig. 18.—SHOWING HOW A BETTER GRADIENT FOR A MAIN DRAIN CAN BE OBTAINED BY SETTING THE GULLY AT A HIGH LEVEL

in order to obtain necessary fall for the drain. Fig. 18 shows a case in which a better gradient was obtained for the main drain by setting the gully at a high level. The gully was raised about one foot and set in a concrete foundation and the surrounding ground was made up to the level of the gully top.

Gradients for Drains

It is desirable that branch drains in which the flow is small should be kept at a steep gradient. This gradient is generally not less than 1 in 40 for 4-in. drains, and 1 in 60 for 6-in. drains. Where it is certain that the drains will be fully flushed, say by means of an automatic flushing cistern, flatter gradients are permissible. If a 4-in. drain with a gradient as flat as 1 in 90 has a flush which will cause it to run half full bore the velocity of the current will be sufficient to move all solid matter. Thus it must be remembered that if a flushing tank of sufficient size is provided at the head of any drain so as to produce a self-cleansing flow, it will be perfectly safe to lay a 4-in. drain with a fall of 1 in 90 or less.

A Useful Rule

Perhaps there is general acceptance of a rule, which errs on the side of safety, that the minimum gradient in house drains must be 1 in 40 for 4-in. pipes and 1 in 60 for 6-in. pipes, but the rule is arbitrary and should not be regarded as binding, unless the by-laws of the district make the demand, and even then reasonable relaxation can probably be obtained if the design is such as to ensure a proper self-cleansing flow. The

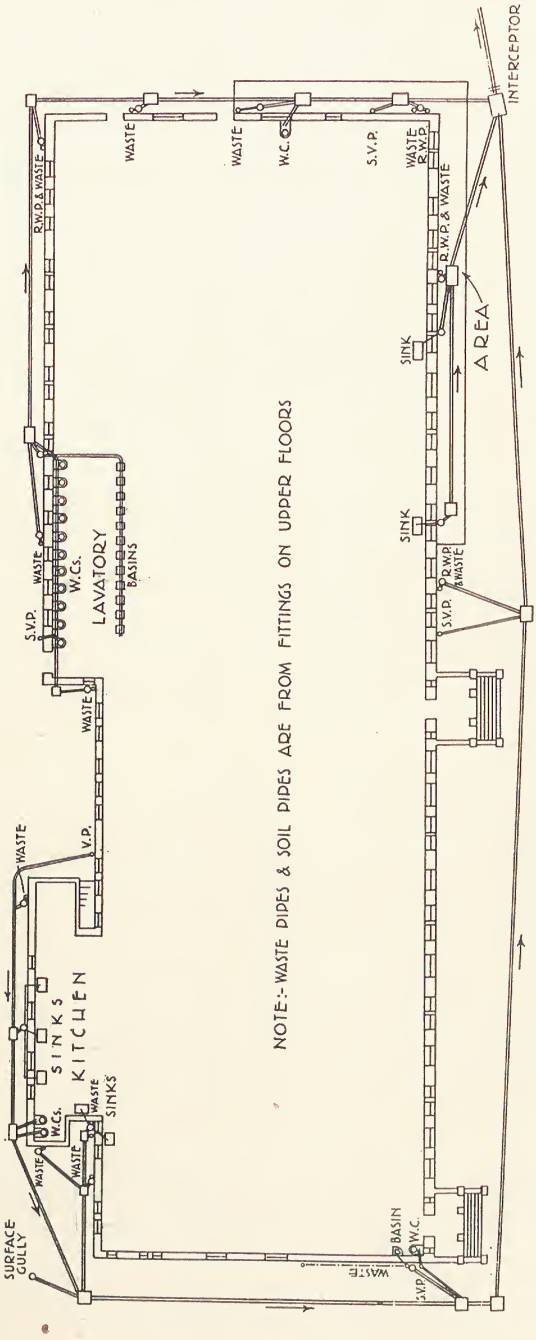


Fig. 19.—AN ACTUAL EXAMPLE OF A COMPLICATED DRAINAGE SYSTEM AT A SCHOOL, DUE TO THE FACT THAT THE SANITARY FITTINGS WERE DISTRIBUTED ABOUT THE BUILDING WITHOUT ANY REGARD TO DRAINAGE FACILITIES. COMPARE WITH FIG. 20

by-laws of the London County Council, for example, demand that drains shall have a minimum diameter of 4 in. and shall "be laid with a suitable fall"; no maximum or minimum gradient is stated.

If the upper branches of a drainage system are kept at as high a level as possible it will follow that whatever saving of depth is effected will have its influence on the main drain, and if the main drain happens to be a long one or of any great depth, or if it should pass into wet ground, the saving even of a few inches of depth along its whole course may be of very great importance.

In the foregoing remarks special emphasis has been placed upon the arrangement of gullies for the reason that errors in planning are generally due to lack of appreciation of their object and importance and of the undesirability and

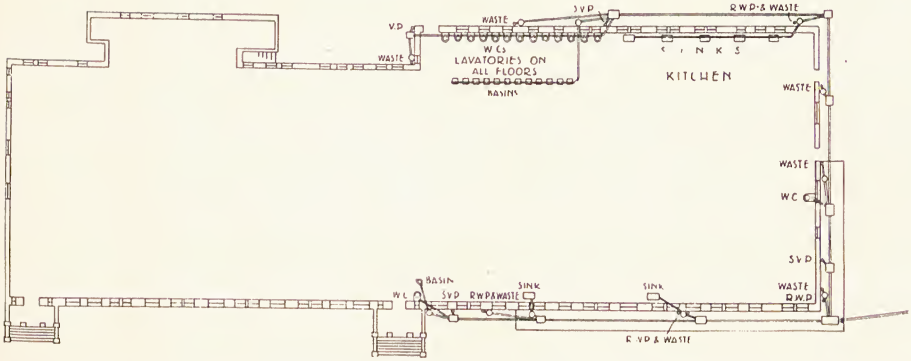


Fig. 20.—SCHEME FOR DRAINAGE WITH SANITARY FITTINGS GROUPED IN BETTER POSITIONS

extravagance of including superfluous gully drains and branches. Such errors are not so likely to occur with regard to W.C. branch drains and soil-pipe connections, because the placing and arrangement of W.C.s will generally receive more careful attention at the outset.

TRAPS AND VENTILATION

Formerly, when drains were very imperfect, quantities of foul matter retained in the pipes became putrid, so that the whole system was foul, and thus the opening of any manhole or the unsealing of any trap resulted in the emission of bad odours. In a modern system of drains the real safeguard is the fact that the drains are clean and that they discharge into sewers which are also clean and thus the drain air is relatively harmless. We all know that when modern sanitary fittings are properly maintained in well-ventilated apartments there is no nuisance. Formerly this was not the case. The better conditions which result from the proper design and maintenance of sanitary fittings such as W.C.s, sinks, lavatory basins, urinals, and baths are to be observed, equally, in good drainage systems which do not smell and which can be kept clean with moderate attention.

Traps and Ventilators

It is necessary, however, to remember that in the best system of drains, stoppages may occur through neglect or misuse, and that in such cases sewage may be held in the drains until it becomes very foul. For this reason traps are necessary, and in order that the traps may not be unsealed by air pressure or by vacuum efficient ventilation is essential. Ventilation throughout the system is necessary also in order that the air in the drains may be kept in a fresh condition and that the interior surfaces of the pipes may have every possible chance of the beneficial effects of oxygen. It is well to bear in mind that any air-inlet ventilator

may at times act as an outlet ventilator. This fact has not been properly grasped in the past and many so-called "fresh air inlets" have been arranged in unsuitable places in consequence.

L.C.C. Requirements

The by-laws of the London County Council require under the heading "Ventilation of Drains," that all ventilating pipes connected to drains shall be carried up to such height and position as to prevent any nuisance or injury or danger to health arising from the emission of foul air. This point is very important. The by-laws of the London County Council are clear and definite. They forbid such dangerous practices as the installation of a fresh-air inlet pipe near doors and windows, but on the other hand allow a certain latitude of interpretation which demands the close attention of those who design drainage systems. It is not a case of working by line and rule, but of exercising the most careful thought with full application of the teachings of experience.

Fig. 19 is an example, taken from actual practice, of a school building in which a most complicated system of drains existed owing to the fact that the sanitary fittings were distributed about the building without any regard to drainage facilities. Owing to this fact and to the fall of the ground the building was surrounded with drains, the greater part of which might have been omitted with advantage if the sanitary fittings had been properly grouped as indicated in Fig. 20. The diagrams do not show the scheme in detail, which would be impossible except on a large-scale drawing, but they indicate the great difference between a well-considered plan and haphazard arrangements.

QUESTIONS AND ANSWERS

Why is it important that Land Drainage and House Drainage should be kept separate ?

If any connection is made between the two the drain air may be carried into the house, and any back-flow due to drain stoppage will fill the subsoil drains with sewage.

When a Combined System of Rain-water and Sewage Drains is employed, what Precautions should be observed ?

Any gully which receives rain water only may become unsealed through evaporation in dry weather, and it is therefore advisable to connect rain-water down-pipes to gullies which receive bath and similar wastes.

Why are Rain-water Drains specially important ?

Because defective drains may cause such troubles as dampness of basements, saturation of house foundations, objectionable outlets of drain ventilation round the house, and pollution of stored rain-water.

HEATING AND VENTILATION

PART II.—RADIATORS, CHIMNEY FLUES AND FUELS

THE familiar cast-iron radiator so extensively used to-day has evolved from the rather ugly pipe coil commonly provided in the early years of hot-water heating. The pipe coil gave place to cast-iron radiators cast in one piece, which were superseded by sectional radiators in which the sections were assembled by the use of " push " nipples. A later development was the method of assembly at present in use, in which right- and left-hand threaded nipples are screwed into correspondingly tapped bosses at the top and bottom of the radiator sections. The tendency in the design of the modern radiator has been to reduce the areas of the waterways, thereby making a reduction of the water content. This effects a saving in the space occupied and a quicker response to fluctuations in the temperature of the system.

Each radiator section may be divided into two, three, four or more columns and they are supplied in various heights from 13 in. to 36 in. A single-column radiator is available for positions such as passages and corridors where the space in front is restricted, and are usually termed wall radiators.

For hospitals and schools it is desirable to use radiators having all surfaces smooth and free from crevices or ledges, where an accumulation of dust would be difficult to remove. Such radiators are standard patterns of the manufacturers and are known as " Hospital " radiators.

It is easy to deduce, that for so many forms of radiators the emission of heat from them will vary with the pattern. The coefficients of transmission published by the manufacturers in their catalogues are based on tests made in their laboratories and can be accepted without question for all practical purposes. The table on the following page gives the B.T.U. per square foot per hour for " Ideal " radiators at various differences in temperature.

The painting of radiators and pipes by ordinary non-metallic paints does not affect the transmission whatever the colour of the paint may be. Metallic paints such as bronze or aluminium reduce the heat emission by about 12½ per cent. Other conditions affecting the transmission are :

(1) Radiator with flat deflecting shield fixed about 3 in. above ; take 96 per cent. of figures given.

TRANSMISSION TABLE

FOR RADIATORS PLACED $2\frac{3}{8}$ IN. FROM WALL * †

BRITISH THERMAL UNITS PER SQUARE FOOT PER HOUR

Ideal Radiators	*Temperature Difference (Degrees Fahrenheit)*							
	Water						*Steam*	
	70	80	90	100	110	120	155	160
Neo-Classic No. 2 ..	116	139	162	185	208	234	327	340
,, ,, 4 ..	106	128	149	170	192	215	300	312
,, ,, 6 ..	100	120	140	160	180	202	282	294
,, Window	99	119	138	158	178	199	278	290
Hospital 3-in. ..	116	139	162	185	208	234	327	340
,, $5\frac{3}{4}$-in. ..	99	119	138	158	178	199	278	290
,, $7\frac{1}{4}$-in. ..	94	113	131	150	169	189	264	275
Classic Wall	106	128	149	170	192	215	300	312
Plain Wall:								
Fixed Horizontally	100	120	140	160	180	202	282	294
,, Vertically ..	64	77	90	103	116	130	181	189
Plain Single Col. ..	100	120	140	160	180	202	282	294
,, Two Col. ..	98	117	136	156	176	197	275	287

* The transmission is approximately the same when the radiator is placed $1\frac{1}{2}$ in. or more from the wall.

† Exceptions are Classic Wall and Plain Wall fixed on standard brackets with 2-in. and $1\frac{1}{2}$-in. centres.

(2) Radiator fixed in open recess. Top of recess about 3 in. above radiator ; take 92 per cent. of figures given.

(3) Radiator encased or with metal hangings in front ; take 80 per cent. of the figures given.

(4) Radiator fixed in front of open fresh-air inlet and under natural draught conditions ; increase figures in table by 30 per cent.

It is not sufficient merely to state the heat transmission from low-temperature flat surfaces used in panel systems of heating, as the heating effect is quite different from that of the ordinary radiator installation. In the radiator system the thermometer is usually relied upon as an index to the comfortable condition of the heated room, but it is a common experience for one to feel chilly even with a room temperature of 63° F. or 64° F. on a cold, sunless, winter day. On a sunny day, especially if the room has a southern aspect, there is often experienced a much warmer effect, though the thermometer may register the same or perhaps a lower temperature.

The reactions of our bodies may be, and most probably are, due partly to the psychological effect of sunshine, but the chief reason for the increase in comfort is that we are benefiting from the radiant heat of the sun. It is on the radiant heat from the flat heated surfaces of the panel system that the heating engineer largely relies, rather than upon convected heat, and makes this the basis of his calculations in arriving at the

amount of heating surface required. Panel heating is a comparatively recent innovation in central heating, and although the success following its adoption has resulted in a wider application of it in one form or another, from which valuable experience has been gained, it will be necessary for further research and experiments to be made before it will be possible to lay down rules of a sufficiently comprehensive character to enable the inexperienced to estimate the correct amount of heating surface for every type of building.

Circulating Pressure

The circulating pressure in any system of hot-water heating, where there is no mechanical device for circulating the water, is the excess of pressure in the return pipe over the pressure in the flow pipe due to the difference in density of water at different temperatures.

If we consider a simple circuit as shown here and assume that the system has been filled but no heat applied, it is true to say the pressure in both flow and return pipes is equal at any common level.

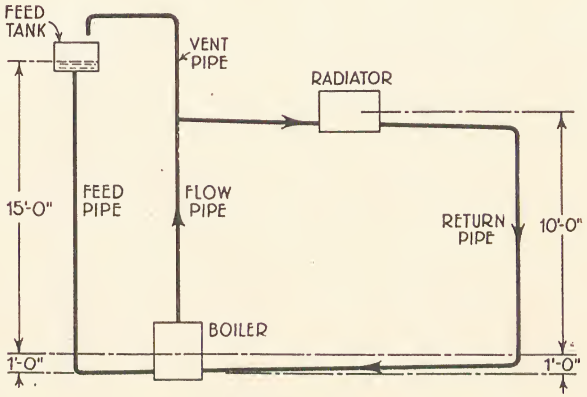


Fig. 1.—A SIMPLE HOT-WATER CIRCULATING SYSTEM
The pressure in the flow pipe is due to the difference in density of water at different temperatures.

In the horizontal return pipe the pressure will be equal to that induced by the height above it of the water in the feed tank. If the height is 16 ft. then the pressure in pounds per square inch is equal to $16 \times \cdot 433 = 6 \cdot 928$. (The factor ·433 is the pressure in pounds per square inch of a column of water 1 ft. high at a temperature of 62° F.) The pressure in the top horizontal pipe is $(15 - 10) \times \cdot 433 = 5 \times \cdot 433 = 2 \cdot 165$ lb. per square inch. In the same way, the pressure at any other level is common to any part of the system.

DENSITY OF WATER AT VARIOUS TEMPERATURES

° F.	*Lb. per Cu. Ft.*	° F.	*Lb. per Cu. Ft.*	° F.	*Lb. per Cu. Ft.*
32	62·418	130	61·571	180	60·560
62	62·355	140	61·388	190	60·324
100	62·031	150	61·201	200	60·081
110	61·89	160	60·998	210	59·820
120	61·734	170	60·783	212	59·769

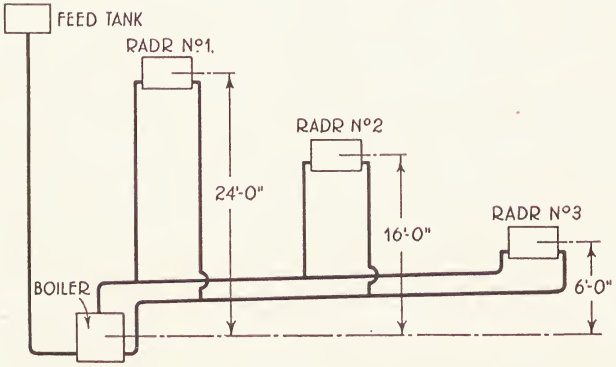


Fig. 2.—HOT-WATER CIRCULATING SYSTEM WITH ADDITIONAL RADIATORS AT DIFFERENT LEVELS

If the boiler is fired, the water in it, on being heated, will expand, causing the density to become less. In this way the pressure conditions are made unequal and a circulation up the flow pipe and continuing throughout the system is set up.

The circulating head or pressure is usually expressed in inches of water column at 62° F. In the following table the values are given for a circuit height of 1 ft. and for various flow and return temperatures.

Mean Return Temperature	*Mean Flow Temperature*				
	150° *F.*	160° *F.*	170° *F.*	180° *F.*	190° *F.*
110° F.	·127	·165	·204	·244	·288
120° F.	·096	·131	·173	·211	·261
130° F.	·069	·108	·146	·186	·230
140° F.	·035	·072	·111	·152	·196
150° F.		·035	·077	·117	·161
160° F.			·038	·079	·123

Assuming that in the circuit under discussion the mean flow and return temperatures are 180° F. and 150° F. respectively, then the circulating head will be ·117 × 10 = 1·17 in., the factor 10 being the circuit height of the system, i.e. from the centre of the boiler to the centre of the radiator. In less simple circuits, where additional radiators at different levels are involved, various circuit heights will have to be considered, as the example which follows will show.

Here the circuit heights and the corresponding circulating heads, assuming the mean F. and R. temperatures to be 180° F. and 140° F., are :

	Circuit Height	*Circulating Head*
Circuit serving radiator No. 1	24 ft.	24 × ·152 = 3·648 in.
Circuit serving radiator No. 2	16 ft.	16 × ·152 = 2·432 in.
Circuit serving radiator No. 3	6 ft.	6 × ·152 = ·912 in.

In a simple single-pipe circuit the mean height of the system must be ascertained, as the following example will serve to illustrate.

	B.T.U.
Let the total emission from radiators 1 and 2 and pipe on same floor ..	= 15,000
Let the total emission from radiator 3 and pipe on same floor	= 9,000
Let the total emission from radiators 4, 5 and 6 and pipe on same floor	= 21,000

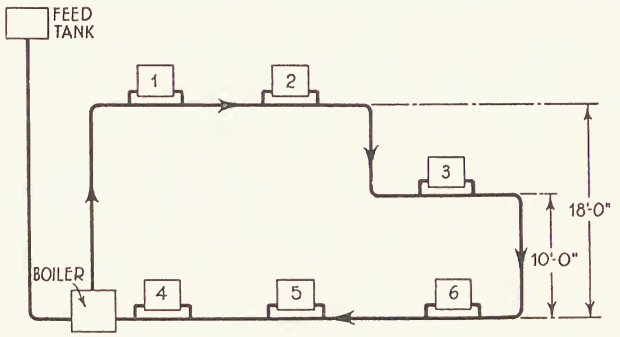


Fig. 3.—IN A SIMPLE SINGLE-PIPE CIRCUIT THE MEAN HEIGHT OF THE SYSTEM MUST BE ASCERTAINED

then the mean circuit height will be the sum of the products of the height of each circuit and the radiation at that height, divided by the total radiation.

$$\text{Thus} \quad \frac{(15{,}000 \times 18) + (9{,}000 \times 10) + (21{,}000 \times 0)}{15{,}000 + 9{,}000 + 21{,}000}$$

$$= \frac{270{,}000 + 90{,}000 + 0}{45{,}000} = \frac{360{,}000}{45{,}000}$$

$$= 8 \text{ ft.}$$

The circulating head, assuming the mean flow and return temperatures are 180° F. and 150° F., will be

$$8 \times \cdot 117 = \cdot 936 \text{ in.}$$

Pipe Sizes

The sizes of pipes commonly used by the heating engineer are : $\frac{3}{8}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in., $1\frac{1}{2}$ in., 2 in., $2\frac{1}{2}$ in., 3 in., and 4 in. The sizes given indicate the approximate inside diameter. Wrought iron or mild steel piping is obtainable in three weights : Gas, Water, and Steam being the terms used to distinguish them. Water-quality tube is of ample thickness for most low-pressure systems and is tested to 700 lb. per

Nominal bore in.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4
External diameter in. ..	$\frac{11}{16}$	$\frac{27}{32}$	$1\frac{1}{16}$	$1\frac{11}{32}$	$1\frac{11}{16}$	$1\frac{23}{32}$	$2\frac{3}{8}$	3	$3\frac{1}{2}$	$4\frac{1}{2}$
Thickness (Wire Gauge Nos.) ..	12	11	10	9	8	7	7	6	6	6
Approx. weight lb. per ft. ..	·644	·896	1·268	1·833	2·598	3·237	4·128	5·779	6·834	8·945
Screw threads per in.	19	14	14	11	11	11	11	11	11	11
Contents, gal. per ft.	·0047	·0084	·019	·0339	·053	·0763	·1356	·212	·305	·543
Square ft. surface per lineal ft. ..	·18	·221	·275	·346	·434	·494	·622	·753	·916	1·175

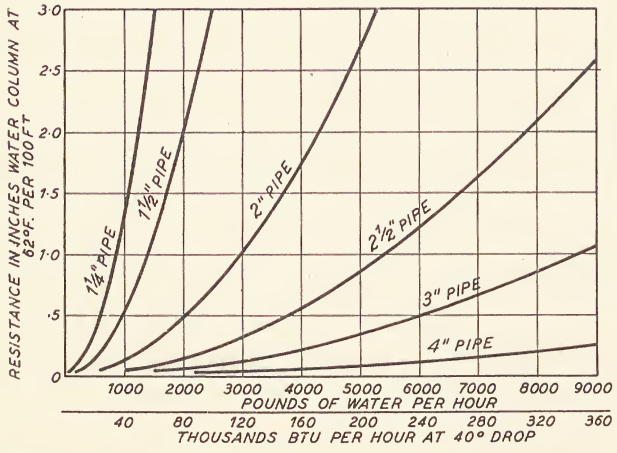


Fig. 4.—PIPE CAPACITIES FOR ACCELERATED WATER-HEATING SYSTEM

Showing the resistance of different sizes of pipes for rates of flow varying from 500 to 9,000 lb. of water per hour.

square inch by the manufacturers. The table on page 37 gives some useful data in relation to it.

In sizing the pipes for a gravity or accelerated system of heating it is necessary to understand that sufficient water must circulate through the system to convey the heat to the radiating surfaces. It is obvious that as the heat is given up by the water, so the temperature will drop, the actual number of degrees in the fall of temperature depending on the rate of flow through the system. For most gravity circuits the pipes are sized on a permissible drop of 40° F. between the flow and return temperatures at the boiler. We know that 1 lb. of water heated through 1° F. equals 1 B.T.U., therefore 1 lb. of water heated through 40° F. equals 40 B.T.U. If we consider a radiator capable of transmitting 4,000 B.T.U. at a temperature difference of 100° F. between it and the surrounding air, then, if the permissible drop is 40° F., the rate of flow through it must be equal to 4,000 ÷ 40 = 1,000 lb. per hour, at a mean temperature of 100° F. above the temperature of the air. The selection of a pipe large enough to carry this quantity will be decided by considering the circulating head available and the resistance to the flow set up by the circuit.

Assuming that the length of the circuit, including an allowance for the extra resistance of various fittings, is 100 ft., and that the height of the radiator is 10 ft. above the centre of the boiler, then the circulating head for a flow temperature of 180° and return of 140° will be 10 × ·152 = 1·52 in. The size of pipe must necessarily be one which will carry 1,000 lb. per hour through a length of 100 ft. with a total resistance of less than 1·52 in.

As will be seen from the accompanying charts, a 1¼-in. pipe will be required, since, with a flow of 1,000 lb. per hour the resistance through 100 ft. is 1·35 in.

It is the writer's practice to consider the capacity of pipes in terms of B.T.U., and since 40° is a common allowance for temperature drop, a second row of figures has been added to the chart, giving the B.T.U.

capacities under such conditions. By this method the division of the B.T.U. load by 40 is rendered redundant.

In making allowance for the resistance of fittings in the pipe line, it is usual to consider this in terms of equivalent lengths of straight pipe, and the following values may be taken as fair allowances.

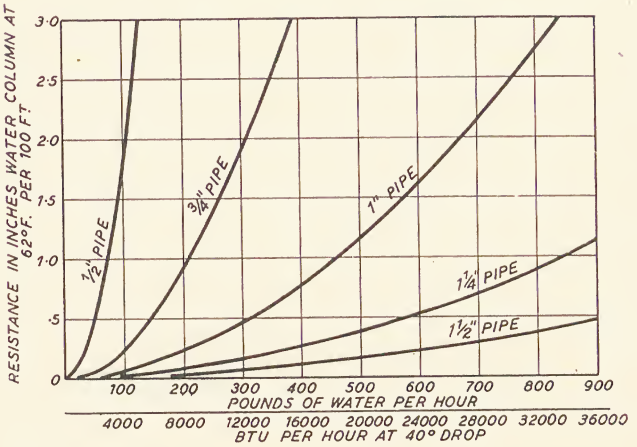


Fig. 5.—PIPE CAPACITIES FOR ACCELERATED WATER-HEATING SYSTEMS

This gives the resistance and capacities for small-bore pipes, i.e. from ½-in diam. to 1½-in diam., and for deliveries of 0–900 lb. of water per hour.

Resistance of Fittings in Lengths of Pipe (ft.) of Equal Diameter

Diameter of pipe ..	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	4 in.
Sharp elbows	1	1·5	2	3	3·5	4·5	6	7	10
Round elbows ..	0·5	0·75	1	1·5	1·75	2·25	3	3·5	5
Globe valve, boiler flow end, radr. return end	2	3	4	6	7	9	12	14	20

Pipe Fittings and Supports

The fittings commonly used in the pipe lines are of malleable iron ; those made to conform to the British Engineering Standards Association specification have taper threads tapped to the same taper as the pipe threads. This makes it possible to obtain a metal-to-metal joint which may be used under the most exacting conditions. The use of standard fittings is of especial advantage to the draughtsman and pipe-fitter as by reference to the tables of dimensions published by the B.E.S.A. they are able easily to estimate the space occupied by the fittings in such places where the space available is limited.

Two tables of dimensions are published, one giving the sizes of what are termed " Short " ordinary fittings and the other the sizes of " Long Sweep " fittings. Elbows, for instance, come in the category of short fittings, while the term " bend " indicates a long sweep fitting. In gravity circuits it is advisable to use long sweep fittings wherever possible in order to minimise frictional resistance.

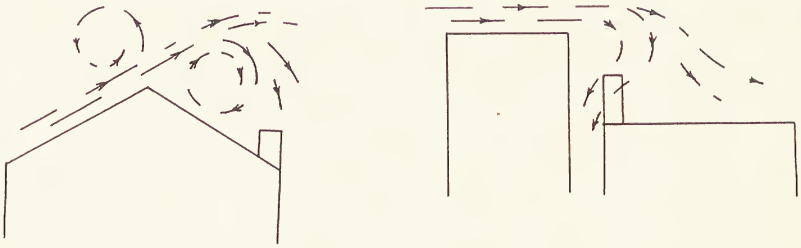


Fig. 6.—SHOWING HOW SURROUNDING HIGH BUILDINGS MAY BE THE UNSUSPECTED CAUSES OF DOWN-DRAUGHTS

Various patterns of supports are available in all sizes, and the illustrations given in the makers' catalogues are of valuable assistance in helping the engineer to decide on the most suitable pattern. For schools and hospitals a pipe bracket built into the wall is preferable to a support from the floor, as it is desirable that there should be no obstruction to hamper the effective use of the sweeping-brush.

All pipes should be supported at intervals of approximately 8 ft.

Chimney Flues

The importance of a properly constructed chimney of adequate height and area must not be underrated if satisfactory results are to be obtained from the boiler. The chimney serves two purposes: one, to carry off the products of combustion; two, to create sufficient pulling power for the air to be drawn through the fire and flues of the boiler in order to maintain efficient combustion of the fuel.

A circular cross-section is the most efficient, and if a square or rectangular flue is used, approximately 80 per cent. should be taken of the total area and regarded as effective. The difference in the length and breadth of a rectangular flue should not be greater than the ratio of 3 to 2.

The height and position of the chimney must be carefully considered, and if down-draughts are to be avoided the top should extend above the ridge level of the roof. Surrounding high buildings or trees may often be the unsuspected causes of down-draughts (Fig. 6).

It is very important that all joints in the brickwork are airtight and that this is understood by the builder employed to build in the iron smoke pipe from the boiler. Care should also be taken to see that the end of the smoke pipe does not project into the chimney and thereby restrict the area. Cleaning doors should always be kept tightly closed.

The use of an existing chimney is naturally the aim of the client who wishes central heating to be installed with the least possible outlay, but the engineer should insist on an examination of any stack that it is proposed to use and should be quite certain that it will be satisfactory before definitely deciding to use it.

In arriving at the size and height of the chimney, the accompanying table may be usefully employed, but allowances must be made if there are any possibilities of undue resistance being offered to the passage of the gases.

TABLE OF APPROXIMATE CHIMNEY CAPACITIES

Size of Flue in In.	*Area in Sq. In.*	*Height of Chimney in Feet*						
		25	30	40	50	60	70	80
		Thousands of B.T.U.						
—	30	40	43	50	57	56	70	75
—	50	85	100	115	130	144	152	158
9 × 9	81	170	200	230	252	266	280	295
14 × 9	126	260	290	330	375	400	430	460
14 × 14	196	—	—	580	650	720	800	860
18 × 14	252	—	—	800	860	940	1,000	1,080
18 × 18	324	—	—	1,080	1,150	1,240	1,330	1,440
24 × 18	432	—	—	1,500	1,600	1,670	1,750	1,800

The effect of the accumulation of soot must also be taken into account, particularly where small flues are used, as the effective area will be reduced considerably by such an accumulation after a comparatively short period of working.

The area of a cast-iron or steel chimney should be approximately 10 per cent. greater than a brick chimney for the same duty, because of the greater cooling effect of the metal as compared with brick.

Fuels (Solid)

The two most commonly used fuels for central-heating boilers are anthracite and coke and, as may be inferred, are probably the most satisfactory. Peat, wood, bituminous coal, and manufactured fuels are sometimes used, but their characteristics tend to rule them out for common use.

PEAT varies greatly in its heating value and is used only when no other fuel is available.

WOOD has a very low heating value when compared with coal and is not often used except in such cases where wood dust or chippings are a waste product of some manufacturing process.

BITUMINOUS COAL is more suitable for use in boilers designed to give smokeless combustion and where the constant services of a boiler attendant are available, such as in steam-raising plants. It can also be used satisfactorily in the underfeed type of automatic stoker which is described later in this section. Unless some such special provision has been made, its use is likely to result in large volumes of smoke being given off during the process of combustion with corresponding deposits of soot in the boiler flues and chimney.

ANTHRACITE contains a comparatively small proportion of volatile matter, a high carbon content, and has therefore a high calorific value. A good draught is necessary for its satisfactory combustion, which is characterised by an intense heat and the almost entire absence of smoke.

COKE is a fuel which also requires a good draught for its combustion. It is smokeless when being burnt and its calorific value is practically the same as the original coal from which it is obtained.

A mixture of anthracite and coke is often found to be a very satisfactory fuel under certain conditions.

The size of the fuel should be graded according to the size of the firebox. For small boilers the lumps should be from $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. and for large boilers from 2 in. to 4 in.

The approximate calorific values and composition of different solid fuels are given below.

TABLE OF APPROXIMATE COMPOSITION OF VARIOUS FUELS

Kind of Fuel	*Approximate Composition Per Cent.*				*Total B.T.U. per lb.*
	Carbon	*Total Hydrogen*	*Sulphur*	*Ashes and Incombustible Matter*	
ANTHRACITE, best	95	1·5	0·5	3·0	*Average* 14,700
,, ordinary	90	3.0	1·5	5.5	
,, poor	85	3·0	2·0	10·0	
COAL, best	84	5·0	2·0	9·0	14,150
,, ordinary	80	5·0	1·0	14·0	12,500
,, poor	75	6·0	1·0	18·0	10,000
COKE, best	97·5	—	0·8	1·7	14,000
,, ordinary	85	—	1·5	13·5	12,500
,, poor	65	—	1·5	33·5	9,000
PEAT, dried	60	*largely water* 6·0	0·3	*including water* 33·7	9,000
WOOD, dried	50	6·0	—	*including water* 44·0	7,800

Oil Fuels

Although the cost of oil as a fuel precludes it from more general use, it is a fuel which can be burnt with a high percentage of efficiency. The calorific value is approximately 19,000 B.T.U./lb. and when burnt in an ordinary heating boiler an average efficiency of 75 per cent. is obtained. Its composition is, by carbon 85 per cent., hydrogen 12·9 per cent., sulphur 1·5 per cent., oxygen and nitrogen ·6 per cent.

The theoretical quantity of air required for its combustion is 190 cubic ft. per lb., but this figure should be increased by 20 per cent. in practice.

Light fuel oil flows freely at comparatively low temperatures, but the tax of £1 per ton has impelled users to consider heavy oil, which is not covered by this tax. The viscosity of the latter renders it necessary, before it enters the burner, to heat it to a temperature at which it flows freely and is more readily atomised.

Gas

Coal gas is used fairly extensively, but in order that the maximum efficiency shall result it is applied only to specially designed boilers.

Its heat content is approximately 500 B.T.U. per cubic foot and the price is usually given in pence per therm. The *therm* is equivalent to 100,000 B.T.U.

Care has to be taken to ensure that the flue pipe is properly designed, and it is advisable to follow the instructions of the boiler makers in this connection to be certain of safe and satisfactory results.

Value of Fuel Constituents

CARBON generates approximately 14,000 B.T.U./lb. when completely burnt.

FREE HYDROGEN generates about 62,000 B.T.U./lb., but it should be remembered that part of the hydrogen in fuel is not free, but combined with oxygen as water.

SULPHUR generates about 5,500 B.T.U./lb. when burnt.

QUESTIONS AND ANSWERS

How does the paint on a radiator affect the heat emission ?

Non-metallic paints do not affect the emission appreciably, whatever their colour. Metallic paints reduce the heat emission by about $12\frac{1}{2}$ per cent.

In a simple circulating system as shown in Fig. 1, what would be the circulating head, assuming a mean flow temperature of 190° F. and a mean return temperature of 120° F. ?

Using the Table on page 36 we find that each foot of height in the system gives ·261 in. of head, hence the total circulating head will be $\cdot 261 \times 10 = 2 \cdot 61$ in. of water.

Express this head in lb. per sq. in.

1 ft. of head equals a pressure of ·433 lb. per sq. in. Hence 2·61 in. of head is equivalent to $\cdot 433 \times 2 \cdot 61 \div 12 = \cdot 094$ lb. per sq. in.

SANITARY SURVEYING

PART I.—TESTING DRAINS

THE purpose of carrying out a sanitary survey is to ascertain the general sanitary conditions which exist within or around premises, which may or may not be injurious or dangerous to the health of the occupiers.

The Sanitary Surveyor

For the work to be carried out efficiently, the person entrusted with the survey should have a thorough knowledge of drainage work, plumbing, and building construction, and be up-to-date regarding local by-laws and modern sanitary construction. There are a number of reputed plumbing contractors and associations who specialise in this business.

The importance of the work cannot be over-rated, as the health of the inhabitants is at stake, and it should be remembered that the local sanitary officer cannot be employed to report on the sanitary condition of empty properties. His function so far as surveys are concerned is to investigate when the occupier has complained to the local authority of a nuisance existing.

Where Defects May Occur

From a sanitary aspect, there are several possible sources of defects, such as drains, vertical soil and waste stacks, closets, baths, sinks, lavatory basins, urinals, and bidets, water cisterns, damp walls, and, in addition, the hot-water system. We shall, therefore, examine these items in turn with the object of noting possible defects.

Testing of Drains

There are various methods for testing drains, and these are employed according to the planning of the drainage system. In dealing with modern drains, one would expect to find access chambers or manholes, at least one at the front of the house and one at the rear.

Front Manhole

In the front manhole chamber, an intercepting trap is connected to the main pipe leading to the sewer, which receives the discharges from all the fitments, while the water seal of the trap forms a barrier to sewer gas and rats. To the upper portion of this chamber is connected the fresh-air inlet to the drain, which consists of a mica flap valve (Fig. 1) intended

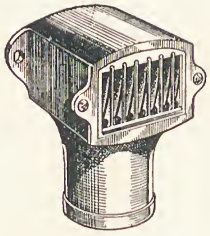


Fig. 1.—MICA FLAP INLET VENTILATOR

Usually fitted to a 4-in. iron pipe which is connected to the front manhole.

only to allow air to pass into the drain and closing when a back pressure of air occurs, due to discharge from a fitment.

Rear Manhole

Connected to the rear manhole a ventilation pipe is fixed, and may take the form of a soil pipe to which one or more closets may be connected. Thus we have a drain through which a current of air can pass throughout its entire length and be "air-flushed," as shown in Fig. 2.

Water Test

The water test should be applied to the modern drain or even old drains where manholes exist, and consists of inserting a rubber expanding stopper (Fig. 3) or a bag stopper (Fig. 4) into the main drain, where it enters the front manhole, and allowing the water from the taps of the fitments to fill the drain until the top of the lowest fitment is reached, which is invariably the yard gully at the rear. To enable the water in the gully to remain steady, it is necessary to pass a rubber tube under the seal of the gully, so as to reach the crown of the trap and release the compressed air, and thus obtain a steady water level. It may be necessary to treat the ground-floor water-closet trap similarly.

If the drain and rear access chamber are sound, the water will maintain its full height, but if the water level is lowered it may be that the drain or the manhole, or both, are defective.

To locate the defect, a separate test should be applied to the drain alone ; this can be done by inserting a second stopper in the drain where it leaves the rear manhole and fixing a tube with funnel attachment from the stopper up to ground level. Now recharge the drain with water, noting the level in the funnel attached to the tube (Fig. 5).

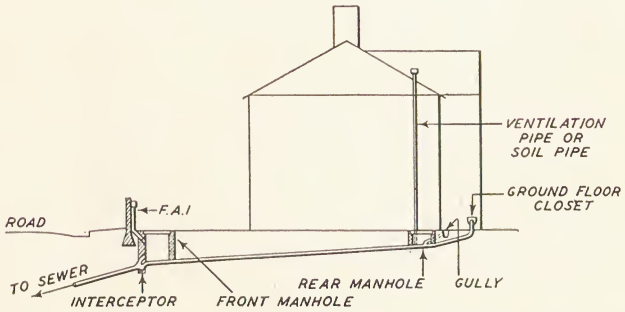


Fig. 2.—SHOWING HOW A CURRENT OF AIR CAN PASS THROUGHOUT THE ENTIRE LENGTH OF A DRAIN

Branch Drains

The branch drains connected to the rear manhole can be tested separately, noting the result of each. It may be necessary when testing the branch drain to the soil pipe to fill the latter up to the first closet

to obtain a water level, especially if there is not an access cover at the foot of the soil pipe, which is often the case.

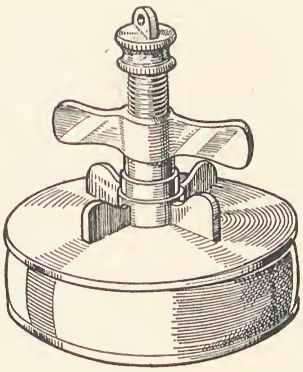


Fig. 3.—EXPANDING RUBBER DRAIN PLUG

Testing the Rear Manhole

To test the rear manhole, leave all the stoppers in the inlets; next place a bag stopper in the outlet and test this bag for its soundness by inspecting the front chamber to see if any water is passing through. The rear chamber can then be filled with water and tested. Thus a complete record of the entire drain is obtained.

Detecting Leaks

The writer has often gained valuable assistance when testing drains and manholes which have been found defective, by careful observation after the water has been released, by noting the constant trickle of water through a branch drain, or at the junction of the centre channel and the cement benching, or from under the section bend where it is bedded on to the centre channel. His deduction is that the water which has passed out through the defects has built up a small head, and, therefore, finds its way back.

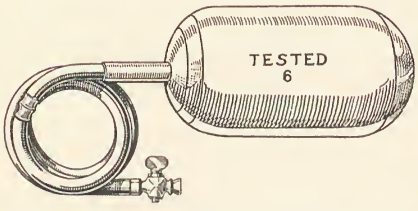


Fig. 4.—AIRBAG STOPPER, INFLATED BY MEANS OF AN AIR PUMP

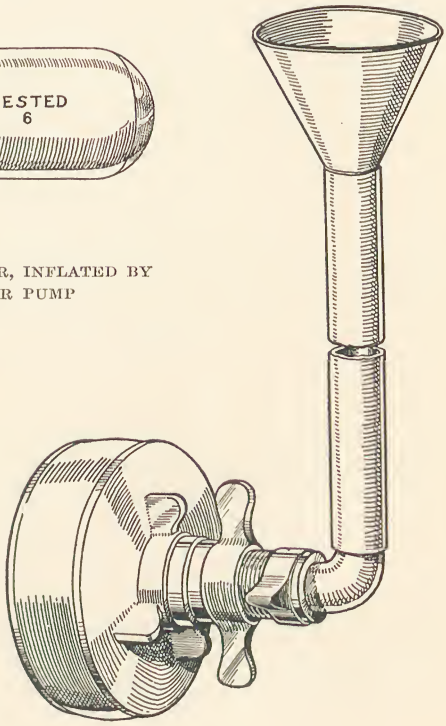


Fig. 5.—DRAIN PLUG WITH FUNNEL ATTACHED

Smoke Test

Sometimes one has to carry out a drain test where no manholes exist. In such a case a smoke test is the next best method, especially if a smoke machine is used, as a slight pressure within the drain can

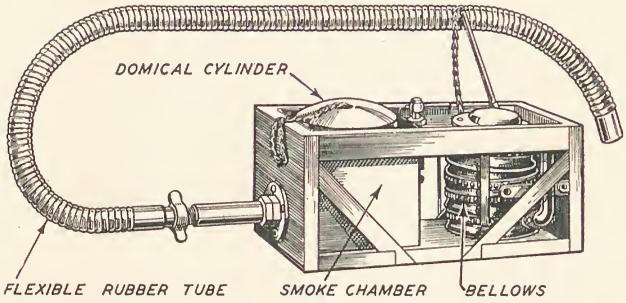


Fig. 6.—SMOKE MACHINE FOR TESTING DRAINS

be obtained. The popular type of machine consists of a smoke chamber with a 6-in. water seal, a detached domical cylinder retaining the smoke, and a bellows actuated by a lever (Fig. 6). A $1\frac{1}{4}$-in. rubber hose is connected to the smoke chamber and passed under the water seal of a gully (Fig. 7).

Smoke is obtained by firing oily waste or prepared smoke paper, contained in the smoke chamber and supplied with air from the bellows, which, at the same time, forces the smoke through the rubber tube into the drain. Care must be taken to ensure that any water which may get into the tube is blown out before pumping in smoke.

The pumping is continued until smoke is forced through the soil or ventilation pipe, which is then stoppered off with a drain plug. It is well to select a gully as near the front manhole as possible, so as to ensure that the full length of drain is charged with smoke. This method is only practicable where the drain has an intercepting trap, which is usually in the form of a running trap, i.e. there is no access to the trap.

The pumping of smoke should proceed for some considerable time, and if by chance (which is not often) the drain and soil pipe are perfectly sound, the domical cylinder covering the smoke chamber will be raised to a permanent position, and by shutting off the air cock attached to the bellows, an air test is virtually carried out on the system.

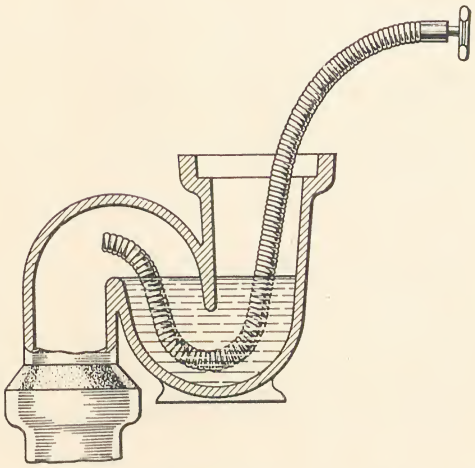


Fig. 7.—SMOKE PIPE PASSED THROUGH SEAL OF GULLY

If the drain is very defective, i.e. open joints or defective pipes, it is quite possible for smoke to be forced through the earth, over or near the course of the drain. If smoke is not seen or smelt (it has a very pungent odour) one cannot say that the drain is sound, but only that no defect has been traced.

Chemical Test

In the case of testing old drains, without manholes, the chemical or scent test is sometimes used, but is not so efficient as the smoke test. The underground drain has to be in a bad condition for the chemical fumes to find their way through the earth. The writer has had positive results from defective drains to houses, which have been rat infested, the apertures in the drain being large enough for rats to find their way out and infest the space beneath the flooring, and the chemical fumes have followed this course. The smell arising can be likened to carbide gas. There are a number of chemical tests on the market (as shown in Fig. 8), all of which require water to produce the fumes.

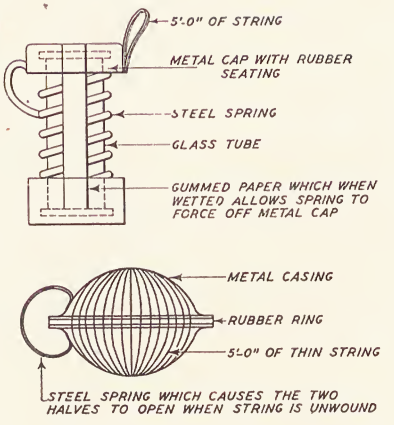


Fig. 8.—CHEMICAL TESTERS FOR TESTING OLD DRAINS

The amount of chemical supplied in the sealed containers does not exceed a dessertspoonful, which is released within the drain, via the closet trap by a spring device, after water has been flushed through the trap. It is well to seal off the ventilating or soil pipe so as to retain the fumes within the drain. If the fumes have not been detected after an hour, it does not signify that the drain is sound, but only that no defect was found.

QUESTIONS AND ANSWERS

What is the function of the mica flap inlet ventilator fitted to front manhole?

To provide fresh-air inlet to the drain while preventing the escape of sewer gases.

If you had to carry out a drain test on a system not provided with manholes, which test would you employ ?

The smoke test.

In using a smoke machine for testing drains, what precautions must be observed ?

Care must be taken to ensure that any water in the flexible smoke tube is blown out before pumping in the smoke.

THE DRAINAGE OF BUILDINGS

PART II.—BY-LAWS

IN every district in this country the local sanitary authority has the right to exercise a strict supervision over house drainage and to make by-laws. The by-laws, to be effective, must have been confirmed by the Ministry of Health, who have issued model by-laws for the guidance of local authorities when framing their own. These model by-laws have to be adapted to suit the special conditions of the various districts. In some cases the by-laws of the authority may be non-existent, incomplete, or obsolete, and in certain cases they may not be rigorously enforced; elsewhere they are perfectly up to date and of such a nature as to give valuable guidance. In any case, it is the duty of those who lay drains to study with care the by-laws of their local authority, and failure to do so and to follow them may result in liability for penalties. It will, however, be found that if a drainage scheme has been well designed, with the intention of doing perfect work, it will not offend against any by-laws, and will be approved by the officers of the sanitary authority, but it is necessary to obtain this approval as a preliminary.

Perhaps the most helpful procedure will be to refer briefly to the model by-laws published by the Ministry of Health as far as they relate to drains, and then to give an example of by-laws as actually enforced by a local authority.

MODEL BY-LAWS OF THE MINISTRY OF HEALTH

The first requirement is that the drain shall be constructed of good, sound pipes of glazed stoneware, heavy cast iron, or other equally suitable material. Each drain must be of adequate size, and must be laid with watertight joints to a proper fall; if it is to carry sewage, the minimum diameter is to be 4 in. The drain must be properly supported and protected against injury; it if passes through any building, it must be constructed of heavy cast iron or of other equally suitable metal. The drain must be laid on a bed of good concrete where it comes anywhere within 50 ft. of the building, unless it is constructed of heavy cast iron or of other metal of not less strength, or unless the nature of the ground renders the precaution unnecessary. Cast-iron pipes in the ground have to be suitably protected against corrosion.

Drains must not be laid so as to pass under any building if any other mode of construction is practicable. A drain laid under a building must

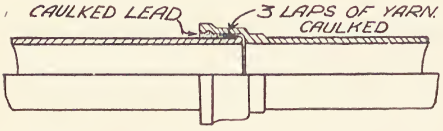


Fig. 1.—CAST-IRON PIPE JOINT

run in a direct line for its whole extent beneath the building, if possible; but where this is impracticable, inspection chambers must be provided at each change of direction, the drains being laid in straight lines. Adequate means of access must be provided for the whole length of any drain beneath the building.

If a drain laid in the ground under a building is constructed of any material other than heavy cast iron, or metal of equal strength, it must be completely surrounded with solid concrete at least 6 in. thick. Every inlet to a drain, other than the ventilation inlets, must be properly trapped; drains connected to sewers or to cess-pools must be disconnected by means of a trap situated as far as possible from the building and as near as practicable to the point at which the drain empties, if possible within the curtilage of the building; such traps must be provided with proper means of access for cleaning. No trap, however, is required for any drain discharging into the open air. This by-law does not demand a trap for a drain joining a combined drain serving two or more buildings when the combined drain is provided with a suitable trap.

A branch drain must join any drain into which it empties, obliquely in the direction of the flow. At least one ventilating pipe must be provided to the drains of a building, which pipe must be situated as near as practicable to the building and as far as practicable from the point at which drains empty into the sewer; a soil vent-pipe may serve for such ventilation.

The by-law does not require the ventilation of any drain not more than 30 ft. in length which does not have any internal communication with the building, other than a water closet entered from the external air. Inlets to the drain, except by means of trapped gullies fitted with suitable covers, or by means of such inlets as may be necessary for w.c. connections, may not be made within the building.

With regard to the giving of notices, the by-laws require that every person who shall execute such work as is described shall give the surveyor of the council at least 24 hours' notice in writing of the date and time at which the execution of the work will be

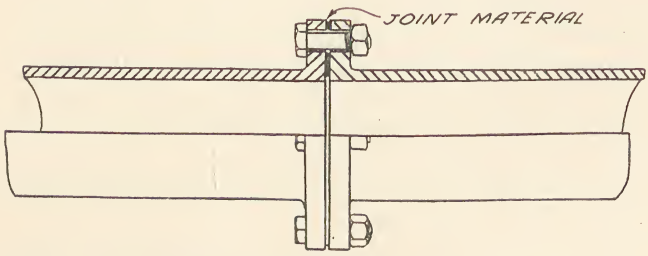


Fig. 2.—FLANGED PIPE JOINT

commenced. Penalties for non-compliance with the by-laws are mentioned.

It will be observed that these model by-laws deal with general principles rather than with matters of detail, and are intended to suggest the lines upon which by-laws are to be framed rather than to lay down hard-and-fast rules in matters of detail.

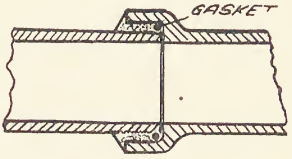


Fig. 3.—STONEWARE PIPE JOINT

BY-LAWS OF A LOCAL AUTHORITY

It is impossible to give any example of by-laws which can be taken as being applicable to the whole country.

Rural and urban requirements differ, and special conditions produce special requirements. For example, a town or district in which all sewers are new and self-cleansing may decide to dispense with interceptor traps between the house systems and the sewer, because the air in the sewer will not be foul and may be ventilated through the house vent-pipes with safety.

It will be instructive to refer to the general procedure of a typical London borough. When any builder or other person wishes to carry out drainage work, he has to apply for a printed form of application at the council offices. A printed form is supplied, to which are attached by-laws and requirements, and also a special form which has to be signed by the borough engineer after the scheme has been approved.

The requirements on the application form are to the effect that no work may be commenced until certain specified information has been given and until the application has received the approval of the borough council, and has been signed by the engineer. The name and address of the owner of the property are required, and also those of the builder or other person making application.

A plan, with a section of the proposed drainage, on cloth or linen to a scale of not less than $\frac{1}{16}$ in. to a foot, showing certain specified details, is required. It is emphasised on the form that the drain shall have a true line and gradient which shall not be less than 1 in 40 for a 4-in. drain, 1 in 60 for a 6-in. drain, and 1 in 90 for a 9-in. drain. Each house must have a separate connection to the sewer, and no drain may be covered until it has been inspected and tested by an officer of the council.

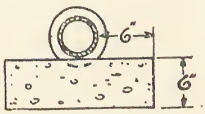


Fig. 4.—DRAIN ON CONCRETE BED

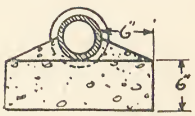


Fig. 5.—SHOWING CONCRETE HAUNCHED UP TO NOT LESS THAN HALF EXTERNAL DIAMETER OF PIPE

No drain may be laid until the sewer connection has been made, and a sum of money, to pay for the expenses of such connection and of the reinstatement of the paving of the public streets, must be deposited with the council.

These are some of the special requirements made

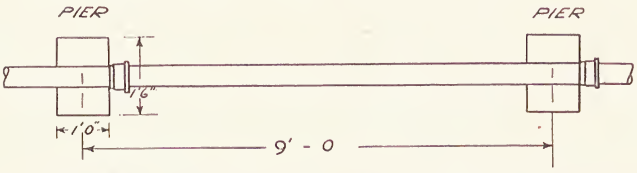


Fig. 6.—CAST-IRON DRAINS ABOVE GROUND MUST BE ADEQUATELY SUPPORTED AT EACH JOINT

by the borough council for work done within its district, but the main requirement is that all work shall be carried out in conformity with the by-laws of the London County Council. These by-laws are attached to the form.

DRAINAGE BY-LAWS OF THE LONDON COUNTY COUNCIL

The by-laws of the London County Council are naturally in agreement on main principles with those issued by the Ministry of Health as a model, and it is therefore unnecessary to repeat what has been stated above; on the other hand they are more definite in matters of detail and, as they stand, provide a specification for the bulk of the work which is likely to be included in the majority of house-drainage schemes in the London area. They go further than the model by-laws. For instance, the model by-laws specify watertight joints, but the L.C.C. by-laws state exactly how these joints are to be made.

Subsoil drains are described in some detail. Surface-water drains are specified as being of the same nature and quality as sewage drains. The rain-water drains, however, are not specially described but are regarded as sewage drains, and the same requirements therefore apply.

Sewage Drains

For sewage drains a "suitable fall" is specified; they must be laid, where practicable, in straight lines. The joints for cast-iron spigot and socket pipes are to be made with a gasket of hemp or yarn and metallic lead properly caulked (see Fig. 1). Cast-iron flanged pipes must be securely bolted together, with some suitable insertion (Fig. 2). Stoneware pipes, or pipes of material other than metal, must have socket joints with a gasket of hemp or yarn and cement or other "equally suitable materials" (Fig. 3). Drains must be laid on a bed of concrete not less than 6 in. thick, projecting on each side of the drain to a width of not less than 6 in. (Fig. 4). Concrete must be filled in so that it shall extend to the full width of the concrete bed, and it must be haunched up to

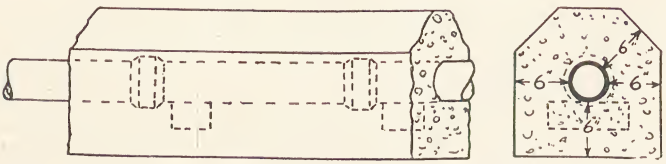


Fig. 7.—FOR DRAINS UNDER BUILDINGS, STONEWARE PIPES LAID ON A 6-IN. BED OF CONCRETE AND ENCASED IN CONCRETE AT LEAST 6 IN. THICK ARE PERMITTED

not less than half the external diameter of the pipe (Fig. 5). Cast-iron drains above ground must be adequately supported at each joint (Fig. 6).

Drains under Buildings

For drains under buildings, stoneware pipes laid on a 6-in. bed of concrete and encased in concrete at least 6 in. thick are permitted (Fig. 7). Cast-iron pipes laid on a bed of concrete which is filled in and haunched up to not less than half the external diameter of the pipe may be used as an alternative (Fig. 8). Above the ground, cast-iron pipes may be carried on piers or other supports through a building (Fig. 9).

Drains beneath a Wall

When a drain passes beneath a wall it must be protected by means of a relieving arch or other support, which must not bear on the drain (Fig. 10). Inlets to the drains from covered trapped gullies may be made inside the building if such connections are indispensable. These covered gullies have to be ventilated to the external air (Fig. 11).

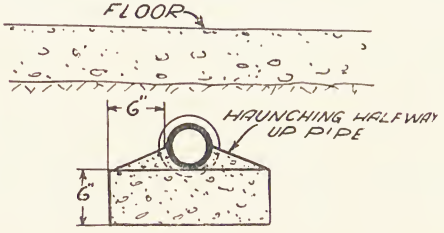


Fig. 8.—CAST-IRON DRAIN LAID UNDER BUILDING

Traps

The trap to any drain inlet must have 2 in. of water seal when the inlet has an internal diameter of not less than 3 in., and a 3-in. water seal when the inlet has an internal diameter of less than 3 in. (Fig. 12).

Gullies

The gullies must be covered with gratings, the bars of which shall not be more than $\frac{3}{8}$ in. apart. The interceptor trap must be provided with a raking or clearing arm fitted with a secure stopper as a means of access between the trap and sewer ; it must have a water seal of at least 2 in. (Fig. 13). The drains must be watertight and capable of resisting a pressure of 5 ft. head of water (Fig. 14).

Inspection Chambers

They must be provided with means of access, e.g. inspection chambers, which shall be watertight and fitted with covers at ground level (Fig. 15). If such means of access comes within or under a building, or on a drain to which no intercepting trap has been provided, " it shall be furnished with a suitable screwed or bolted airtight cover (Fig. 16), and where the means of access is in the form of a manhole, such cover shall be fixed

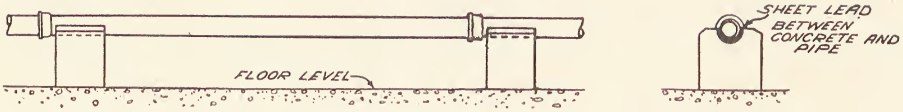


Fig. 9.—CAST-IRON PIPE ON PIERS

to the channel of the manhole and be in addition to the cover at the level of the adjoining ground surface."

Ventilation of Drains

For the ventilation of the drains, if an intercepting trap is provided, there must be at least two ventilating pipes, one near the intercepting chamber and the other as nearly as possible at the head of the drain. If an intercepting trap is not provided, at least one ventilating pipe is required at the head of the system. "Every such pipe shall be carried up vertically to such height and position as to prevent any nuisance or injury or danger to health arising from the emission of foul air." These ventilation pipes must have an internal diameter of not less than 3 in., and must be provided at the foot with a suitable airtight access cap or cover (Fig. 17).

Soil Vent-pipes

Soil vent-pipes are held to be proper ventilation pipes. These pipes must be constructed of lead, copper, cast iron, wrought iron, or other equally suitable material; they must be securely fixed, without unnecessary bends or angles. They must be easily accessible, and protected from damage where necessary. They must have open ends fitted with a suitable grating or other cover having openings equal to the full sectional area of the pipe (Fig. 17). Tables are given of the dimensions of cast-iron drain pipes, ventilation pipes of lead, copper, cast iron and wrought iron, and also the dimensions of stoneware drain pipes.

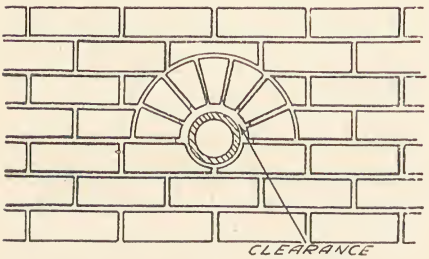


Fig. 10.—DRAINS BENEATH A WALL MUST BE PROTECTED BY A RELIEVING ARCH OR OTHER SUPPORT

Depositing the Plans and Notices

It is required that the plans and notices shall be deposited seven days at least before the work is commenced and, in cases where the drainage work is in connection with a building to be erected, seven days at least before commencing the erection of the building.

The plans must show: the position of all sanitary fittings; the fall of every drain; the position and size

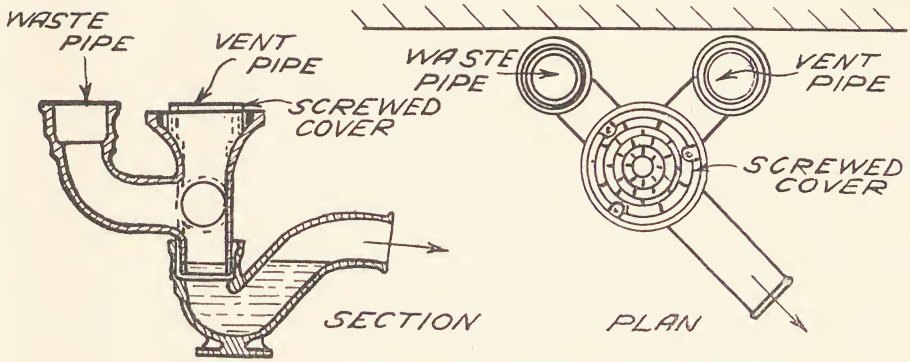


Fig. 11.—SEALED GULLY INSIDE BUILDING

of every drain, means of access, trap, gully, soil pipe, waste pipe, ventilating pipe, and rain-water pipe; the height and position of every chimney; and the position of every window and other opening into the building in connection with which such work has to be executed, within a distance of 20 ft. from the open end of the soil pipe or ventilating pipe; the level of the lowest floor of the building in connection with which drainage work is to be executed; and the level of the adjoining street, and of any yard, area, ground, or open space in connection with the building. A block plan may also be required to a scale of not less than 88 ft. to an inch, showing the premises and buildings and adjoining properties affected.

It should be noted that these requirements are enforced only to such a degree as may be necessary under the particular conditions of each case, and the builder or other person responsible should ascertain from the council's engineer exactly what is required, in the particular case under consideration, when making his plan.

From the above general outline, which gives the main points of the L.C.C. by-laws, but which must not be taken as being fully comprehensive of every requirement, the reader may obtain a fair idea of modern practice and of the care which is now exercised by local authorities to ensure that work shall be perfect. The need for exact knowledge is apparent, for drainage work can no longer be carried out in the haphazard methods of former days. On the other hand, it should be clearly understood that the modern district surveyor and sanitary surveyor are generally highly qualified men of great experience, who should not be regarded as hostile critics; on the contrary, they may be regarded rightly as friends whose experience enables them to give very valuable advice in both the design and construction of drainage systems; whose help should be sought at the outset, and whose disapproval must not be regarded lightly. It will be found that the council's officer will discuss any well-thought-out scheme even if it should happen to depart, to some

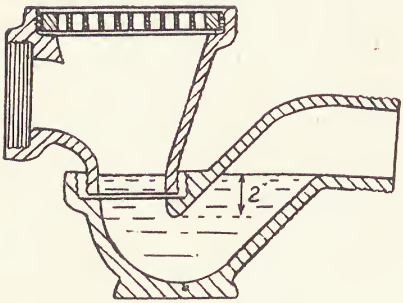


Fig. 12.—THE TRAP OF ANY DRAIN INLET MUST HAVE 2 IN. OF WATER SEAL WHEN THE INLET HAS AN INTERNAL DIAMETER OF NOT LESS THAN 3 IN.

degree, from the by-laws, and permission for any necessary and proper divergence may generally be obtained.

It must be remembered that by-laws are for the prevention of error and bad work, and are intended to give the local authority the power to act as may be necessary for the attainment of this object; but it does not follow that their rigid application is always necessary.

An Important Point

There are two points of great importance to the architect or engineer responsible for drainage work, and to the contractor who undertakes to carry it out. The architect should specify that all requirements of the local authority must be complied with as part of the contract, and the contractor should see that his prices quoted will cover such requirements. Unless this is done there may be serious trouble for the architect and serious loss for the contractor.

Difficulties Outside the By-Laws

By-laws are necessarily of a general character and cannot provide for the many difficulties and possibilities which may be encountered. When these difficulties occur they must be dealt with scientifically in accordance with the needs of the case.

For example, the levels may be such that the specified gradients of 1 in 40 and 1 in 60 cannot be obtained, and it may be necessary to ascertain, by calculation, the actual volume of the flow, its velocity in the pipe, and its clearing effect, and to provide such flushing appliances as may be necessary in order to produce a self-cleansing flow; or again, it may be necessary to lift part or possibly all of the sewage.

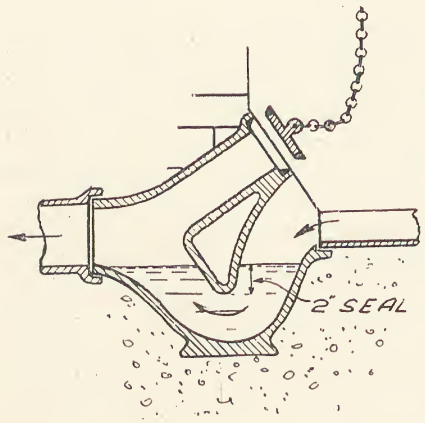
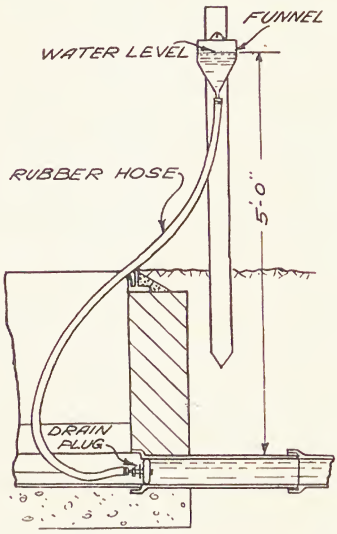


Fig. 13.—THE WATER SEAL OF A GULLY MUST ALSO BE AT LEAST 2 IN.

In some cases what is known as the "one-pipe system" may be installed, in which the waste pipes from sinks and baths, lavatory basins and w.c.s, are all connected into one main down-pipe. This system,

which may simplify the drainage plan considerably, has been adopted for important buildings in London with the approval of the authorities, but by-laws generally take little account of such a possibility. Many other difficult problems may occur which are not covered by ordinary by-laws.



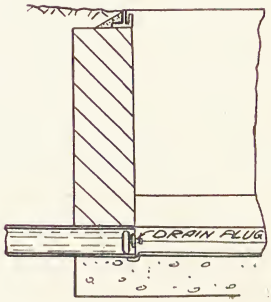


Fig. 14.—GULLY DRAINS MUST BE WATERTIGHT AND CAPABLE OF RESISTING A PRESSURE OF 5 FT. HEAD OF WATER

DRAIN CONSTRUCTION

As will have been observed from the wording of the by-laws and from what has been stated above, there are different methods of drainage and a wide choice of materials, but practically speaking the ordinary methods are as follows :—

(1) Stoneware pipe drains with cement joints and with brick or concrete manholes.

(2) Coated cast-iron pipe drains, the pipes being of heavy water-main quality, with brick or concrete manholes and with stoneware gullies.

(3) Coated cast-iron pipe drains, with cast-iron manholes and with cast-iron gullies and a cast-iron interceptor. Such drains are generally used inside buildings, but are equally suitable for outside work.

(4) Drainage systems in which, the pipes being laid at flat gradients, the velocity of flow is produced by special flushing.

(5) Drainage systems in which the sewage is lifted by means of ejectors, automatic lifts, or by pumping.

(6) Cast-iron drainage systems kept entirely above the basement-floor level.

Setting Out the Work

A great deal of time and trouble may be saved by giving careful attention to the details of work at the outset. Detail drawings of any part of the work in which connections occur will be particularly useful, and consideration of the exact length of each separate section of the drain may save a great deal of pipe-cutting. Similarly, when a manhole is

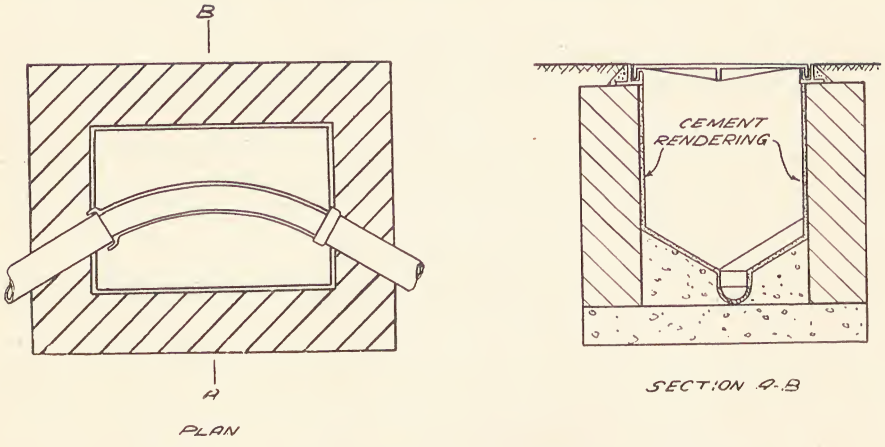


Fig. 15.—ORDINARY INSPECTION CHAMBER OR MANHOLE

designed to receive branch drains it should be ascertained whether side channels can be procured to fit the drain at the angles shown.

The exact centre-lines of the drains should first be set out with pegs on the ground. When this has been done the measurements can be checked, and any slight alteration needed for the sake of convenience in pipe-laying can be made.

A little time spent in considering the proposed layout, with particular reference to the relative positions of the main drain, branch drains, and manhole, will be well repaid. Remember that cast-iron pipes are supplied in 9-ft. lengths as standard. Very often, by changing the position of the manhole slightly, the work can be done without cutting pipes or obtaining special castings or special lengths of pipe.

When the centre-lines of the drains have been fixed, the outside lines of the trenches and manhole excavations can be pegged out.

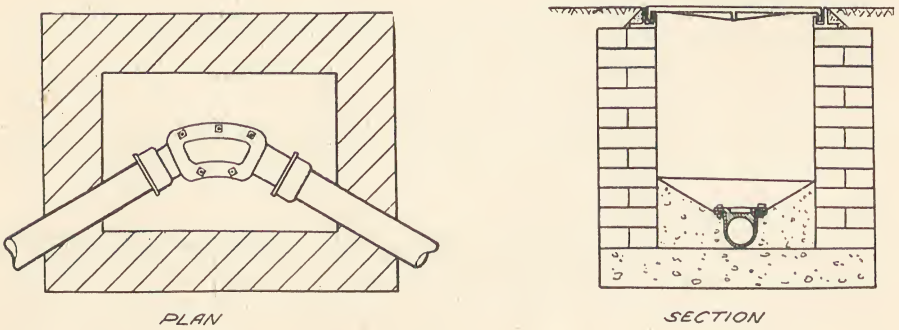


Fig. 16.—MANHOLE INSIDE BUILDING

Levels

It is most important that the levels should be set up accurately. A good deal of work is still done by means of a builder's level and straight-edge, as described in the case of subsoil drains, and it is probably due to this fact and to the attendant possibilities of error, that by-laws demand gradients which are steeper than those which careful calculation would show to be necessary. Even in a small scheme it will be far more satisfactory to have the levels set up by means of a proper surveying instrument. If the drain is very short it will be sufficient to drive pegs in the bottom of the trenches to levels thus obtained, and to lay the work evenly between the two points by means of a straight-edge.

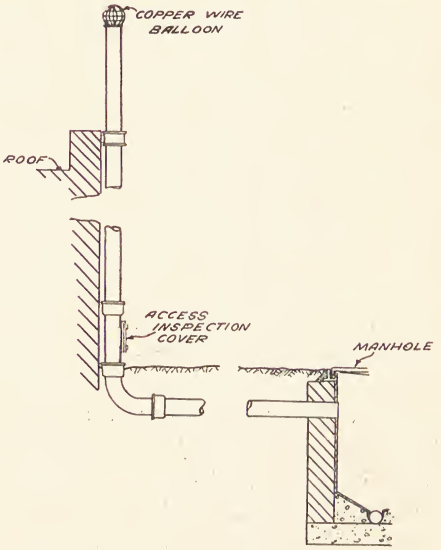


Fig. 17.—VENTILATION PIPE OR SOIL VENT-PIPE

The Trenches

For the longer trenches stout posts, say 3 in. by 4 in. in section, should be driven well outside the line of excavation, at the ends of each section of the drain. The relative levels of the drain invert are marked on these posts, and horizontal rails are fixed at these levels at a convenient height above the drain invert, as shown in Fig. 19.

It will thus be seen that a line of sight taken over the top edges of the rails will be parallel to the gradient of the drain, and that the vertical distance between this sight-line and the invert of the drain must be the same throughout the section. Thus the level of the trench bottom or of the drain invert at any intermediate part can be obtained by using a " boning rod " of the right length, as shown in Fig. 20. This rod is lined in correct position by sighting over the tops of the rails. A shoe fixed on the end of the rod can be placed in the invert of each pipe as it is laid. By using boning rods of suitable lengths, the bottom of the excavation, the level of the top of the concrete foundation, and the line of the invert may be fixed with accuracy as the work proceeds.

It is well to fix the horizontal sight-rails so that they can be removed and replaced easily, and for this purpose holders may be provided as shown in Fig. 21. Where a sight-rail is nailed to the uprights it may easily be damaged in the course of the excavation operations. This possibility should be avoided, as it is apt to lead to error of a serious kind.

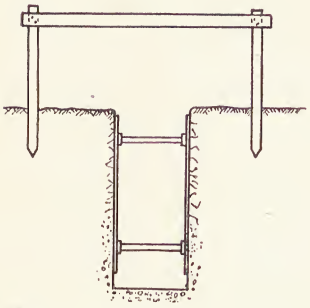


Fig. 18.—CROSS-SECTION OF TRENCH, SHOWING SIGHT-RAIL

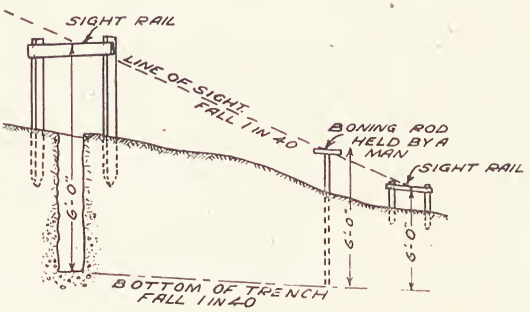


Fig. 19.—SHOWING USE OF SIGHT-RAILS

The trench excavation is generally set out by stretching the line between the pegs and then cutting the outside line of the excavation with a spade or pick. In the case of paved ground a chalked line is sometimes used: this is stretched tight near ground level and snapped down on to the ground so that it marks the surface.

Start the Drain Trench at the Lowest Point

It is well to start the drain trench at the lowest point, viz. at the outlet end, so that any water gathering in the trench may flow away. This can generally be managed, but if no outlet is available any water gathering in the trench must be baled or pumped out, for which purpose it is desirable to make a small sump. Where the trench comes on the side of a hill, and there is the probability of a large run-off coming from the higher ground into the trench, it is sometimes well to cut a small trench on the upper side as shown in Fig. 22, and thus to convey the surface water away.

All top soil, turf, paving, gravel from paths, or road material should be removed and stored for replacement as a preliminary to excavation. The trench should then be excavated, care being taken to avoid superfluous depth, because it will be necessary to fill any extra depth with concrete, refilled material being an insufficient foundation for the drain. All excavated material should be kept well back from the trenches, because the extra weight of the earth piled near the trench may tend to cause falling-in of the sides.

Fig. 20. BONING ROD

When Timbering Is Necessary

In good solid ground, such as chalk, trenches may be carried to a considerable depth without timbering, but it is false economy to take risks. Speaking generally, gravel is a very treacherous material, and although it may appear to be safe, sudden land-slides into the trench may be expected. In deep trenches this

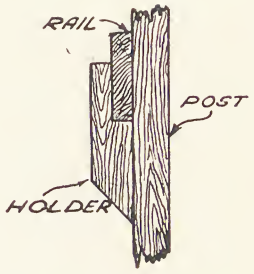


Fig. 21.—SIGHT-RAIL HOLDER

has been known to lead to fatal accidents. Clay, when in a fairly dry condition, may prove to be self-supporting for a reasonable time, and even deep trenches are sometimes made with a very small amount of timbering provided the foreman in charge is aware of possibilities of trouble and has at hand the material and labour required for dealing with any emergency. Where from any cause clay becomes wet it is a very treacherous material, and may collapse badly and suddenly. A collapse of the clay is not, however, quite so serious, as far as the workmen are concerned, as a fall of gravel, because gravel will bury a man completely, whereas clay generally falls in masses, leaving some breathing-space. Sandy formations may be reasonably stable or the reverse.

In some formations, the sides of a trench which would stand without support indefinitely in a dry condition may collapse immediately, owing to the presence of water. Made ground is always treacherous, and should not be trusted to support itself. Local experience is valuable in trench work and an experienced local foreman will generally be able to judge how much support is required, but he should not be allowed to take unnecessary risks.

Trenches have to be supported by timber to the extent which the conditions may require, in order to prevent collapse. It is unwise to econo-

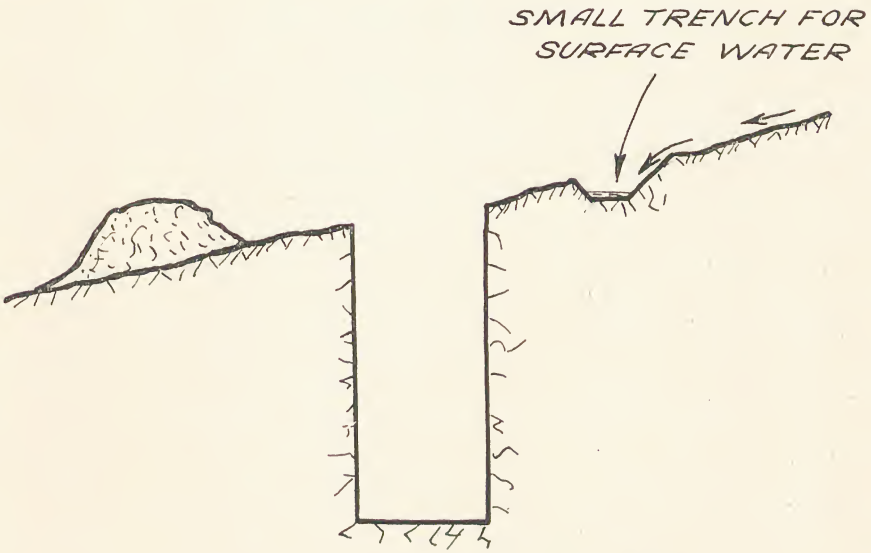


Fig. 22.—DIVERSION OF SURFACE WATER FROM TRENCH

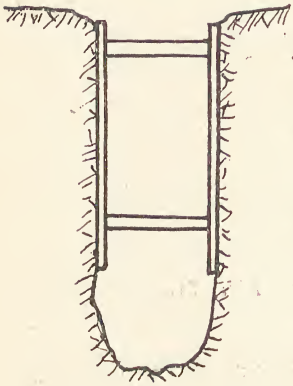


Fig. 23 (*above*).—SIMPLE TIMBERING WITH PINCHERS

The sides of a trench may be supported at any weak point by means of a pair of vertical planks, called "pinchers," about 9 in. by 3 in. in section, fixed on opposite sides of the trench, and held in position by struts, which must be firmly driven.

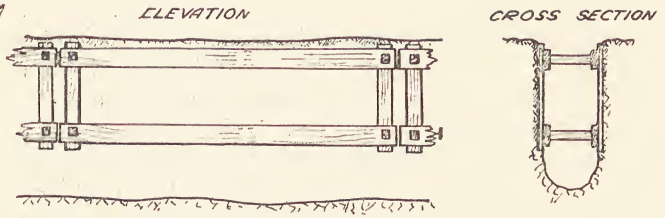


Fig. 24.—SIMPLE TIMBERING IN GOOD GROUND

Timbering for trench made in fairly solid ground to a depth of not more than 5 or 6 ft.

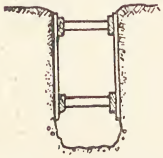


Fig. 25.—TIMBERING IN BAD GROUND

If the ground is of such a nature that it is likely to require extra support, the polling boards should be set against the side of the trench at the start, without any recess.

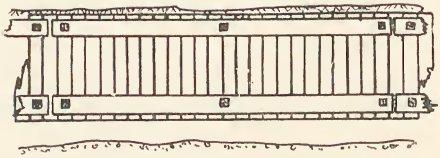


Fig. 28.—DEALING WITH SANDY SOIL.

If the conditions require close timbering, the walling should be 9 in. by 3 in. in section, the polling boards $1\frac{1}{4}$ in. thick, and struts 6 ft. apart.

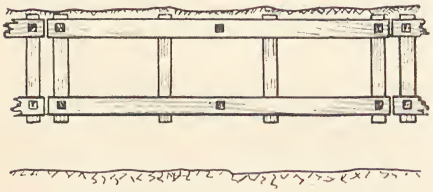


Fig. 26 (*above*).—SIMPLE TIMBERING IN GOOD GROUND

Additional polling boards can be inserted by driving them behind the walings, and additional struts can be fixed if this is found to be necessary.

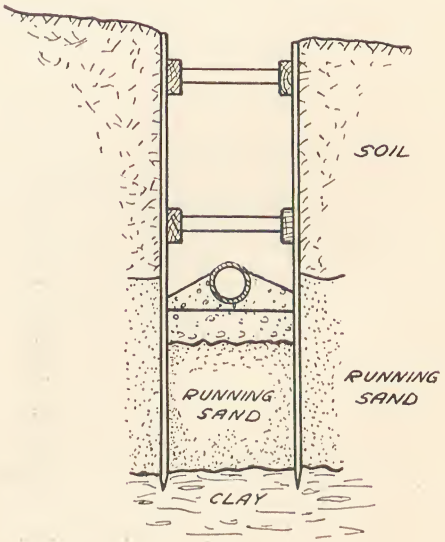


Fig. 27 (*right*).—DEALING WITH SANDY SOIL

Showing how runners can generally be driven through a shallow stratum, to make a fairly tight joint with a solid stratum below.

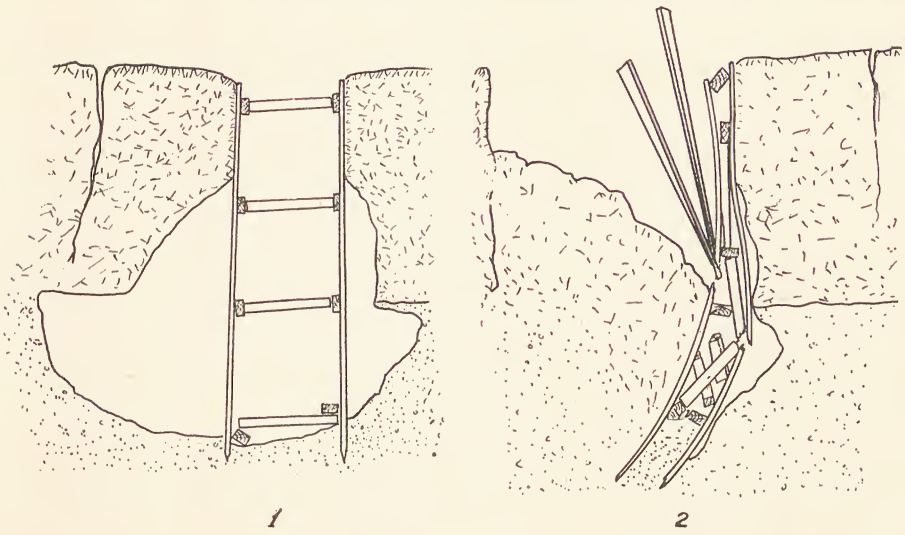


Fig. 29.—SHOWING THE EFFECT OF THE FLOWING IN OF RUNNING SAND

To prevent this, the runners must be fixed close together so as to make tight joints. (See Fig. 28.)

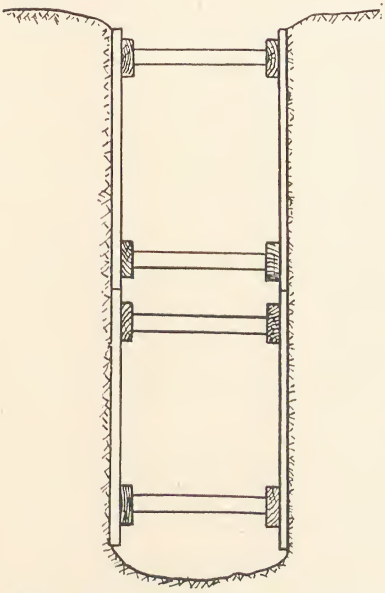


Fig. 30.—TIMBERING IN GOOD GROUND

It is sometimes possible to excavate 4 ft. below the first frame, and to put in two sets of walings for the lower frame without diminishing the width of the trench.

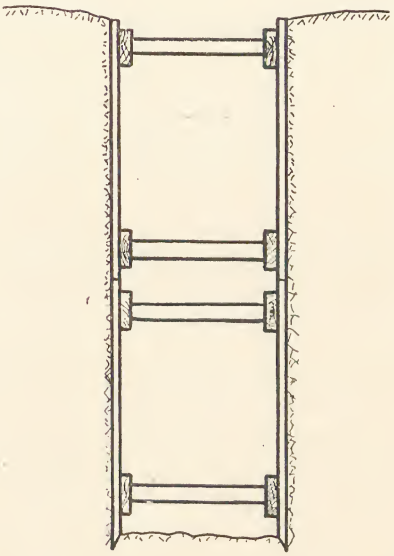


Fig. 31.—TIMBERING IN BAD GROUND

If the width of the trench is not to be diminished, the polling boards of the first frame must be driven down as the ground below is taken out, and other polling boards must be put in to replace them.

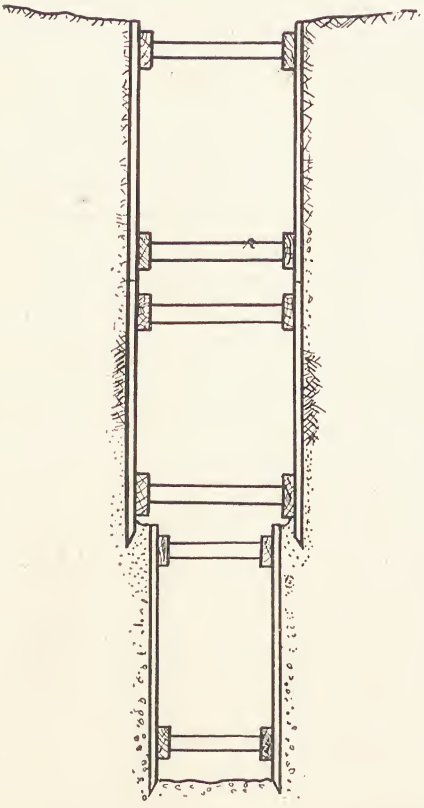


Fig. 32.—WHEN FRAMES ARE REQUIRED BELOW A DEPTH OF 12 FT., THE WIDTH OF THE TRENCH MUST BE DIMINISHED BY ANOTHER FRAME OF POLLING BOARD FIXED AS SHOWN ABOVE

mise in this respect. In the event of the sides falling in, the earth has to be removed from the trenches, and the timbering is then far more difficult. In deep trenches there is the risk of injury to workmen. The chances of injury to the work which has been done in the trench, or which has been partly done, are great, and the cost of setting such injury right is considerable. Very few soils can be trusted to stand entirely unsupported even for a depth of 5 ft., and in some cases support may be required for shallower depths.

The amount of the support required will depend entirely upon the nature of the ground. One great safeguard is to have plenty of timber at hand, so that in case of any weakness becoming apparent the sides of the trench can be supported immediately. With such material available and ready to hand, it is sometimes possible to do work which would be absolutely unsafe if the means of dealing with sudden emergencies were not available.

The first principle of timbering is that any timber work put in should be of such a nature that it can be made more secure rapidly by means of additional timber. It is also necessary, in deep work, that the trench should be of such width that proper space will remain for working after all timbering has been fixed, allowing for the contraction of the lower part of the trench.

Sometimes running sand is encountered even at shallow depths; in this event the very greatest care is required at the outset. No excavation should be made in the quicksand until very definite precautions have been taken. Very serious trouble is sometimes caused by the pumping or removal of running sand; cavities are formed behind the timbering, and subsidences of the ground surface, and possibly of adjoining buildings, may occur, and great trouble and expense may result. [See also the section on Temporary Timbering (Vol. II, p. 28).]

SANITARY SCIENCE APPLIED TO BUILDING

Definition

WHEN the subject of sanitary science is mentioned, it is often taken to mean something of a purely scientific or academic character dealing with principles beyond the scope of the average practical man. It is, however, a matter of extreme interest and importance, covering practically every point in connection with the construction of sound buildings, amid healthy surroundings, which, of course, leads to the general good health and well-being of the community.

In view of this it is necessary to make a study of the subject so as to be in possession of a fair amount of information before deciding on a position for a building and also how such building should be constructed.

To give some idea of the ground to be covered in the study of the subject, the items to be considered may be tabulated as follows :—

Nuisances.
Soils and Sites.
Ground Air.
Ground Water.
Subsoil Drainage.
Construction.

Nuisances

These, of course, should be avoided in the selection of a site for a dwelling, and one would not decide on a position where a nuisance might possibly arise from such things as soap-boiling works, chemical works, and similar places where obnoxious trades are carried on. Sewage disposal works should also be avoided, although modern disposal methods have practically eliminated the possibility of nuisance from this cause, beyond occasional smell, and this is harmless but nevertheless objectionable. One often hears the remark from those who live in the vicinity of sewage works, "It is only noticeable when the wind is in a certain direction"; but as we cannot govern the elements it is best to avoid such sites.

Local Administration

This item will, of course, have a bearing only where

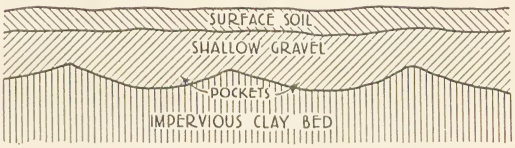


Fig. 1.—IMPERFECT GRAVEL SUBSOIL

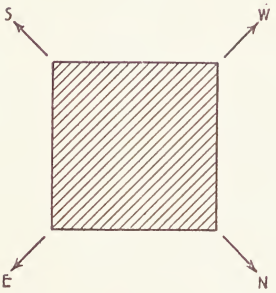


Fig. 2.—ASPECT FOR HOUSE, WITH CORNERS FACING THE FOUR CORNERS, N., S., E., AND W.

towns are concerned, as it cannot be applied to the rural and outlying districts. The reason is fairly obvious. In a town one should inquire as to the provision for: (1) Main drainage and sewage disposal. (2) Good water supply. (3) Efficient system of refuse collection and disposal. (4) Cleansing and lighting of streets. The question of gas supply and electric supply undertakings would also be considered, although not necessarily being under the control of the Local Authority. In outlying districts one would not expect the provisions set out above, and the question of local administration would not apply to nearly the same extent as it would in town districts.

SOILS AND SITES

Natural Soil

Although the mass of the earth is made up of various types of rocks which are represented by granites, sandstones, greensands, limestones, chalk, gravel, etc., it will suffice if we refer to the soil as consisting of surface soil and subsoil. The nature of surface soil varies to a great extent in different places and is usually composed of the decayed upper surface of the rocks beneath, mixed with alluvial deposit and the remains of vegetable and animal matter. Air is admitted to this surface soil by the disintegration caused by worms, moles, ants, and other burrowing creatures, and this air finds its way into the deeper layer or subsoil. The subsoil consists chiefly of inorganic materials caused by the breaking up of the rock by various means. The subsoil should be of a porous nature and should readily absorb and retain heat. Water absorbs heat very slowly, therefore a moist soil is slow to heat, so that a clay soil would absorb heat very slowly, but would lose heat much more quickly than a sandy soil; sands warm more quickly than other soils and retain their heat better.

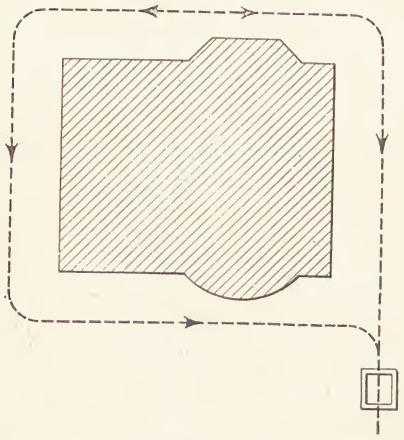


Fig. 3.—SUBSOIL DRAINAGE FOR SITE OF SMALL HOUSE

The temperature of soils has a direct influence upon the temperature of the atmosphere, and in the choice of suitable building sites the class of soil is of great importance.

Made Soils

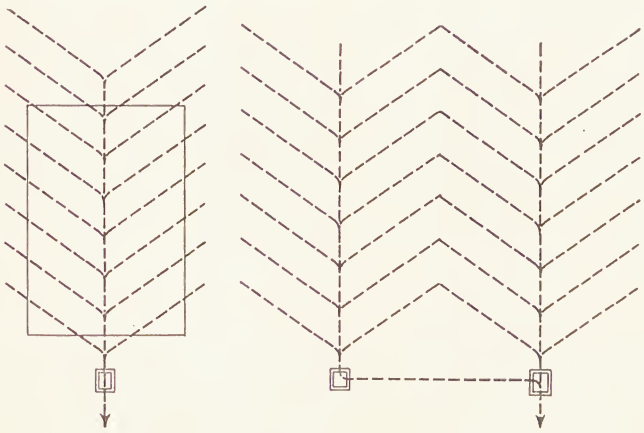


Fig. 4.—DRAINAGE OF LARGE SITE
The pipes are arranged in herring-bone style.

Where excavations have been made for the removal of gravel and sand and also clay, they have usually been converted into rubbish dumps, with the result that all sorts of miscellaneous refuse are deposited until the excavations are filled. When the subsoil is gravel or some other porous material, it is not so dangerous as when the subsoil is clay. These made-up soils should be avoided unless they are subjected to very careful treatment, and in any case a period of five or six years should elapse after the complete filling of the excavations before any thought is given to the use of such a site for building purposes. Made soils are always undesirable no matter how long they have been filled. Alluvial soils, which mean soils upon which matter has been washed from rivers, streams, etc., should also be avoided.

Suitable Soils

A gravel subsoil is considered the best by reason of its dryness and the pure character of its material. It is called dry because of the rapidity with which water can drain away through it, and this is important in the selection of a site.

Although gravel may be quickly found when excavating, it does not follow that the site has all the advantages which gravel is supposed to give. The gravel may be upon a clay bed, which will prevent the water passing away. Therefore, to be effective a gravel soil must be deep, to allow the water to pass well below the surface before it is arrested and drains away in a lateral direction. In certain parts where houses have

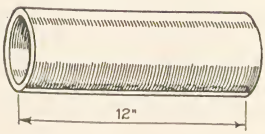


Fig. 5.—EARTHENWARE FIELD PIPE, UNGLAZED

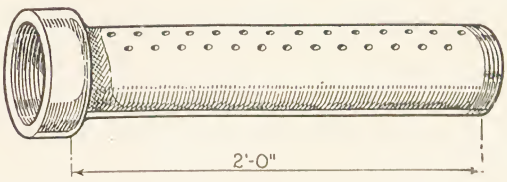


Fig. 6.—GLAZED PERFORATED PIPE

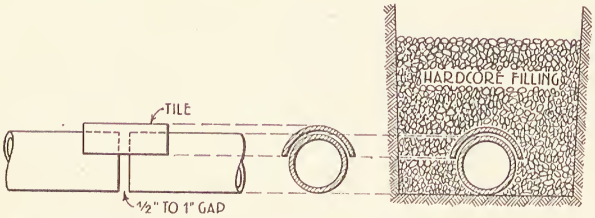


Fig. 7.—METHOD OF LAYING UNGLAZED PIPES FOR SUBSOIL DRAINAGE

Showing section through trench bottom.

been erected on gravel soil the water has been known to rise close to the surface after heavy rain. This would indicate a shallow bed of gravel resting on a non-porous bed just below.

Where a shallow gravel soil has a clay bed just beneath, it will often be found that the clay occurs in ridges, forming pockets or basins in which water can collect, and such soil might be called a clay soil (Fig. 1). When such a thing as this exists, it may be overcome by proper subsoil drainage.

After gravel, the next best in order of suitability are, perhaps, limestones, sandstones, and chalk. Of natural subsoils that are commonly built upon, clay is the worst from a health point of view, unless it is properly treated by an efficient system of subsoil drainage, when it can be rendered free from damp and ill effects.

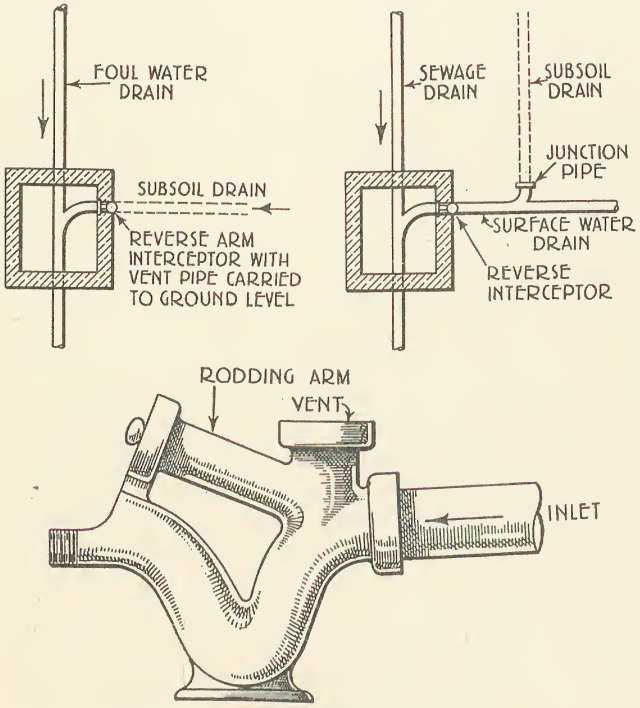


Fig. 8.—REVERSE-ARM INTERCEPTOR

Showing (above) its application to a connection between a subsoil drain and a sewage drain.

Site for a House

To obtain what is generally considered a good site and position, is for a house to stand on ground with a slight slope, having a gravel subsoil of good depth, the house to face south. By sloping ground is not meant the side of a steep hill, neither is it to be inferred that the summit or the foot of a hill is a good position. On the side of a steep hill

there may be protection from the north, but the wind may have a bad effect on chimneys and ventilating pipes. Further, to build a house close in to a hill is not good, as the site may be damp and unhealthy. A projection on the side of a hill affords a good site, but in every case one must not overlook the question of aspect, so that a slope facing south is to be preferred to one facing north. Sloping ground greatly assists in the drainage facilities.

If a house is to be erected on the top of a hill it should be protected from the winds by a belt of trees.

Low-lying areas are to be avoided, as also any hollows or similar places, which are liable to be cold and damp. Table I gives a list of various soils and their suitability or otherwise from a health point of view as building sites. Fig. 2 shows a suitable aspect for a house, and Table II gives the position of the various rooms.

TABLE I

Soil	*Remarks*
(1) Granitic, metamorphic, and trap rocks	Most healthy site, slope being good, natural drainage, ground water nil, dry site.
(2) Clay, slate	Similar to above, one difficulty scarcity of water owing to impermeability of soil.
(3) Limestone and magnesium limestone rocks	Resembles last in good slope. Probability of marsh gas emanating from subsoil. Water runs off quickly.
(4) Chalk soil	If mixed with clay, considered unhealthy, but without clay, healthy.
(5) Sandstones, millstone grit ..	If permeable, healthy; if clay subsoil, considered rather damp; if mixed with clay, damp site.
(6) Gravels	All gravels healthy unless lying below surrounding soils; if so water generally rises in them and are unhealthy.
(7) Sands	May be healthy or unhealthy. When deep and not mixed with organic impurities it is healthy. Organic matter gives off CO_2. Very unhealthy when mixed with vegetation sediment, also when shallow or lying on bed of clay.
(8) Clay, dense marls and alluvial soils	All suspicious; water retained in them cannot get away and only efficient drainage can render them healthy.
(9) Cultivated and made soils ..	Cultivated soils are not necessarily unhealthy, but made soils are always so and should be avoided, owing to the material of which they are formed.

TABLE II

Room	*Approximate Position*	*Remarks*
Dining-room	N. or N.E.	Cool position
Drawing- or sitting-room	S. or S.W.	For afternoon sun
Bedrooms..	S.E.	For invalids
Do.	N.E.	For ordinary use. (Cool at night. Morning sun)
Kitchen. Larder ..	N.	Cool position
Breakfast-room	N. or E.	Cool position
Study or Work-room ..	N.	Longest light

In the summer, bedrooms on the west or south-west side of a house are liable to get unpleasantly hot from the afternoon sun, but when facing north-east they get the morning sun and are much cooler at night. In the winter months of the year, the north-east position will, of course, be found much colder, but would still reap the benefit of any early morning sun. For invalids, etc., the south-east position is to be recommended.

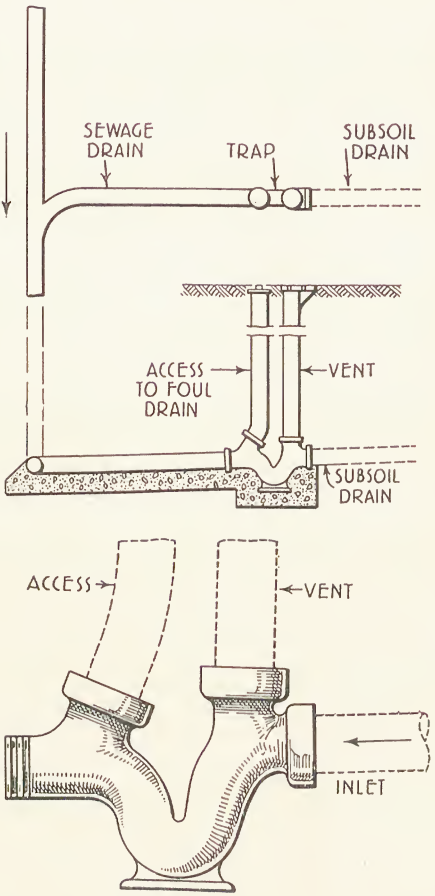


Fig. 9.—DISCONNECTING TRAP, AND ITS APPLICATION TO A CONNECTION BETWEEN A SUBSOIL DRAIN AND A SEWAGE DRAIN

Ground Water

At varying levels below the surface of the soil is a sheet of water termed the *subsoil* or *ground water*. The level of this water fluctuates, and rises or falls with the presence or absence of heavy rains. In some parts of the country this water may be quite close to the surface, whilst in others it may be down a hundred feet or more. In districts where there are shallow wells an inspection of the water level in them will give an indication of the ground water level. For a building site to be really healthy, the ground water should be at least 10 ft. below the surface when at its highest level.

Ground Air

Ground air is that which is contained in the soil above the level of the ground water, and fills all the space not occupied by water or solid particles. The amount of ground air will, of course, vary with the looseness of the soil.

Movement of Air

Now, as the ground water rises and falls, there is a corresponding movement of the ground air, so that it is forced out of the ground as the water rises, and as the water falls back the soil is left moist and full of air.

Air Pollution

This movement of ground water and air may give rise to various happenings: it is possible that owing to leaky drains or cesspools the ground air will become polluted, and on a rise in the ground water this polluted air will be forced out of the ground; there is a possibility also of wells becoming polluted by introducing into them the washings of impure soils. Care should be taken to ensure that subsoils are free from contaminating influences, as foul air forced out of the ground, as in-

evitably it must be, is a menace to the health of the occupants of a building on such soil.

Site Concrete

To prevent the passage of ground air and ground moisture into the interior of a building, the site should be covered with a layer of cement concrete 6 in. thick and, if the cost will permit, covered with a thin layer of asphalte. Failing this, the surface of the concrete should be roughly floated over with cement and sand.

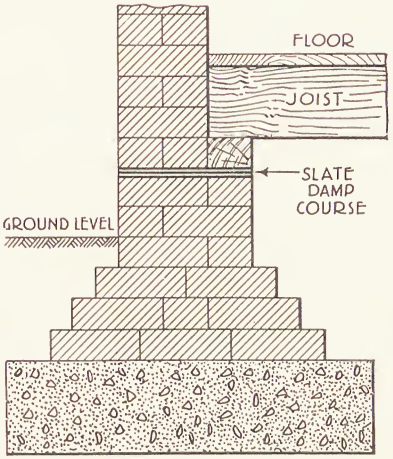


Fig. 10.—ORDINARY DAMP-COURSE IN SLATE

Waterlogged Ground

Much of the land which, by reason of its situation, would be excellent for building purposes, cannot be used, owing to the subsoil being waterlogged. This can, however, be overcome by laying down a system of land drainage to carry off the subsoil water.

Subsoil Drainage

Reference has been made to the necessity for draining the subsoil in order to render a site fit for building purposes. This is also recognised in the Model By-laws, which state that the subsoil must be effectually drained where the dampness of the site renders this precaution necessary. In this clause, site means the ground on which the building stands. In the London area the building, rebuilding, or adaptation of buildings for use as dwelling-houses is under specific control where the surface of the land is below Trinity high-water mark at the entrance to the London Docks.

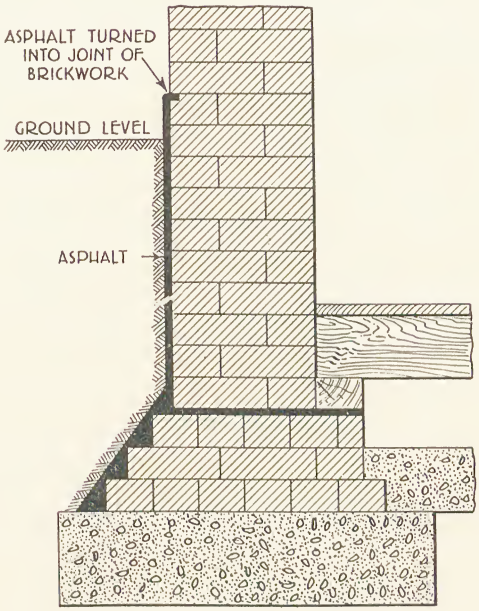


Fig. 11.—VERTICAL AND HORIZONTAL ASPHALTE DAMP-COURSE

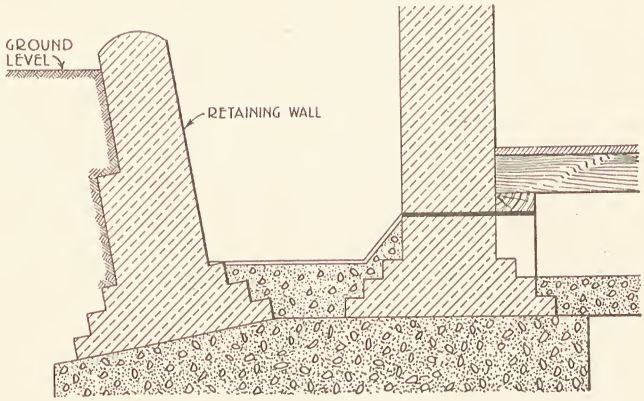


Fig. 12.—SECTION OF OPEN DRY AREA

Planning the Drainage

The general arrangement of the drains for subsoil water varies with the extent of the area to be drained. For a small type of building it may be sufficient for the drain to be laid around the building below the level of the foundations and given a fall to one corner, where a collecting chamber could be provided from which a drain could be laid to carry away the water to a suitable point of discharge (Fig. 3).

Drainage of Larger Sites

Where a site of a larger type is to be drained, the pipes should be arranged on the herring-bone principle, so that the natural flow of water is intercepted by each row of pipes, which should then converge to a main drain or drains. Fig. 4 shows a typical arrangement of the pipes for a large site.

Drain Pipes

The pipes used for land drainage are of various types. Those generally favoured are the unglazed socketless type shown in Fig. 5. Socketed, glazed stoneware pipes, with the upper half of the barrel perforated, are also used (Fig. 6). Glazed stoneware pipes with half-sockets, and also porous concrete pipes with special-shaped ends, are used. In diameter the pipes vary from 2 in. to 6 in.

Laying the Pipes

The pipes should be laid with a suitable fall according to the diameter of the pipes used. The smaller the pipe, the greater the fall should be to ensure the removal of earth washings. The pipes should be laid in straight lines and the bottom of the trench should be made as firm as the soil will allow and with an even fall to preserve a regular invert (Fig. 7).

Porous Filling

When the pipe lines are complete, the trench should be filled for a depth of 9 in. to 12 in. above the pipes with a suitable material such as

broken clinker, ballast, small hard core, as this will greatly assist in the drainage process (Fig. 7). It will be seen in the section that the pipes are laid with the ends about 1 in. apart and the upper part covered with a tile. This tile prevents the entry of earthy matter through the top of the opening.

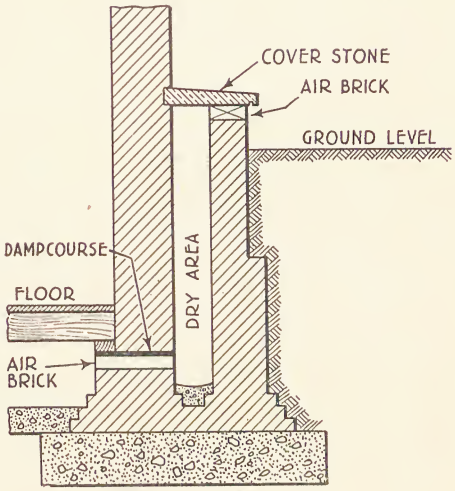


Fig. 13.—CLOSED DRY AREA OR AIR DRAIN

Access and Inspection

Provision should be made for means of access and inspection by providing at least one chamber or inspection pit. If the site drained is very extensive, then it is a good plan to provide more than one.

Discharging Points

Having so far dealt with the method of draining a site, the question arises, What is to be done with the subsoil water ?

In country districts this is not usually a difficult matter, as there is generally a water-course or ditch into which the drain may discharge. Another method is to drain the subsoil water into soakaways, which should be formed well away from the building and not less than 10 ft. distant from the outer walls.

Discharge into Drainage System

If it is not possible to drain the subsoil water as explained above, the next course is to arrange for its discharge into the drainage system. This presents no great difficulty where a drain or sewer exists for the sole purpose of the drainage of surface water.

Sewage Drains

Where it is necessary for a subsoil drain to discharge into a sewage drain or sewer conveying sewage, a proper disconnecting trap and a vent pipe must be provided between such subsoil drain and such sewage drain or sewer. The Model By-laws state that the discharge from subsoil drain pipes must not empty into a sewer, cesspool, or other place for the reception of sewage if other means for its disposal are available.* Figs.

* The L.C.C. By-laws also provide a similar clause and specify the use of a trap and vent pipe.

8 and 9 show various methods of dealing with subsoil drainage when connected to sewage drains.

Reason for Disconnection and Ventilation

It has been stated that subsoil drains are constructed of porous pipes laid with open joints to allow water to percolate. It follows that if there is a direct connection between a subsoil drain and a sewage drain, foul air will pass along the subsoil drain and escape through the open joints and into the subsoil, ultimately finding its way into the atmosphere around and within the building. Owing to the possible emanation from the gases in the subsoil and from decaying matter, ventilation should always be provided to a subsoil drainage system.

Town Premises

In towns the subsoil drainage, when such is necessary, would, of course, have to discharge into the surface water or sewage drain, and the methods shown in Figs. 8 and 9 would be adopted.

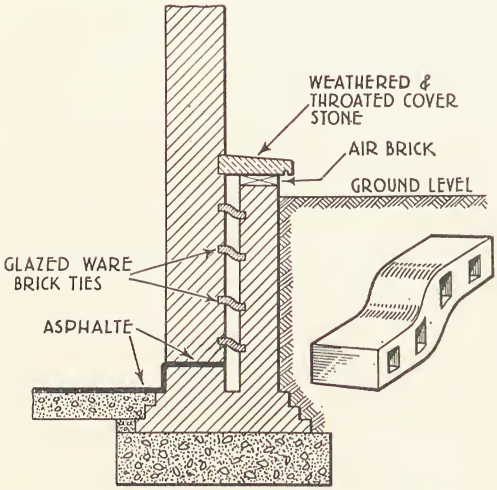


Fig. 14.—ANOTHER TYPE OF CLOSED DRY AREA OR AIR DRAIN

Basements below Sewer Level

Where subsoil drains are provided below the level of the public sewer, the discharge from them may be taken into a sump, from where it could be raised to the discharging level by pumping or other means.

Spacing of Subsoil Drains

It is a matter of local conditions which govern the general layout of a subsoil drainage system. The depth at which the pipes are laid and the distance between each row will depend upon the type of soil to be treated. It is usual to make a series of trial holes to ascertain what will be required in the way of land drainage. The general rule is to space the pipe lines 20 ft. apart, but in soils such as stiff clay this is not close enough and 12 ft. to 15 ft. spacing should be adopted, whilst on the other hand, in very loose soils the spacing may be 30 ft. The depth varies from 2 ft. to 4 ft.

Size of Pipes

The size of pipes used will of course vary with the extent of the area to be drained, and also the type of subsoil. The usual size is 2-in. and 3-in. diameter for the ordinary draining of sites, whilst 4-in. and 6-in. would be used for very large areas and where the subsoil is of a more loose type.

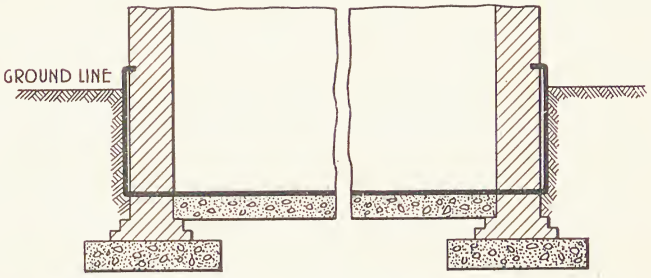


Fig. 15.—ASPHALTE DAMP-COURSE TO WALLS AND FLOOR OF SHALLOW OR SEMI-BASEMENT

GENERAL CONSTRUCTION

We have so far dealt with the conditions to be observed with regard to the suitability of sites for building purposes and we now come to the question: What must be considered to ensure that the building shall be designed and constructed so that it will be in every way habitable and healthy?

In answer, it may be said that almost everything in the planning and construction, as well as the sanitary arrangements, water supply, ventilation, and heating should be included.

Design

In the design of buildings, many points are of first consideration, such as the site available and individual requirements. If, however, one is given a free hand in the choice of a first-class site and the planning of the building, it should not prove a very difficult matter to formulate an ideal design which would embody all the essential points, but such opportunities are seldom presented. The design, therefore, must be on lines to suit the conditions available, but should be such as to ensure the maximum of health and comfort.

Air Space about Buildings

For a building to be healthy there must be ample space to permit of the free circulation of air around such building.

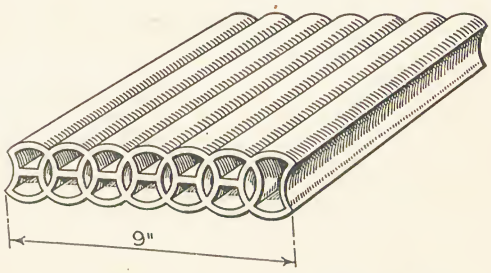


Fig. 16.—SALT-GLAZED DAMP-COURSE

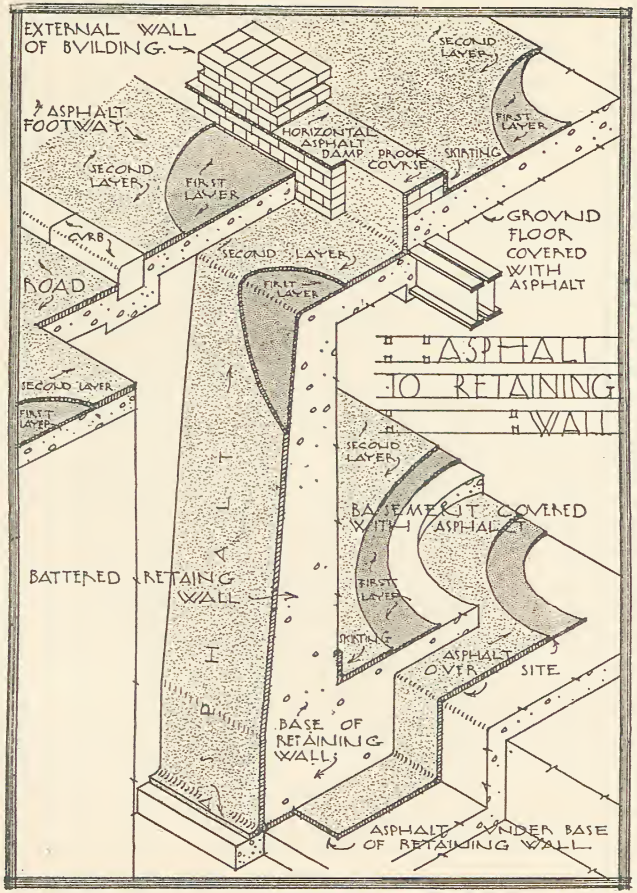


Fig. 17.—Asphalte over entire site of basement

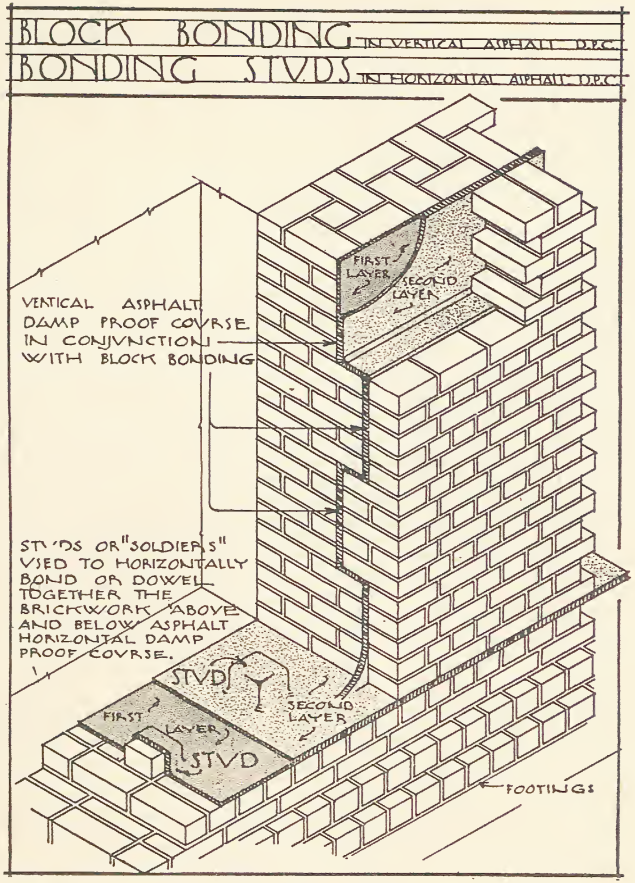


Fig. 18.—Block bonding in vertical asphalte damp-course

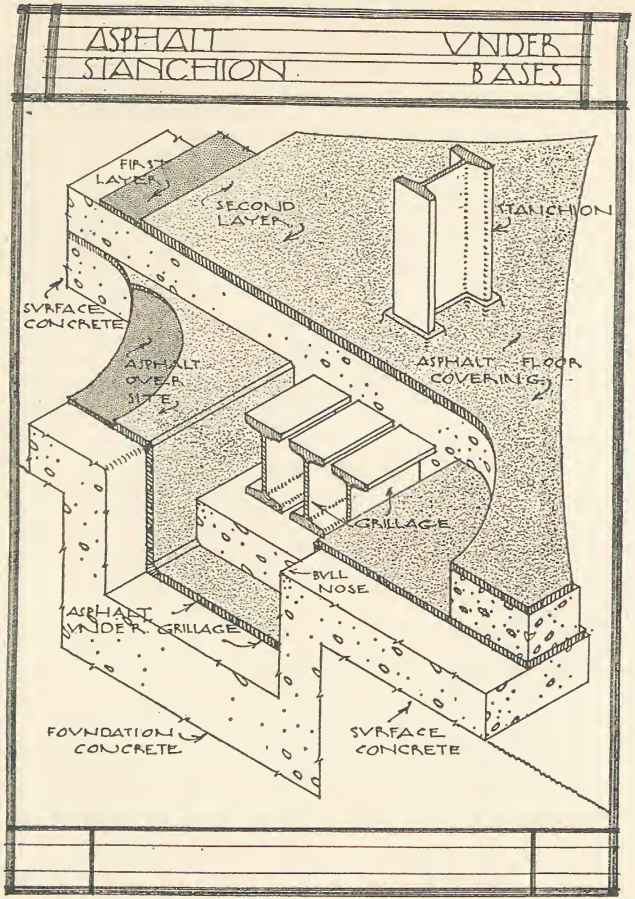


Fig. 19.—ASPHALTE OVER SITE UNDER STANCHION BEDS AND COVERING FLOOR

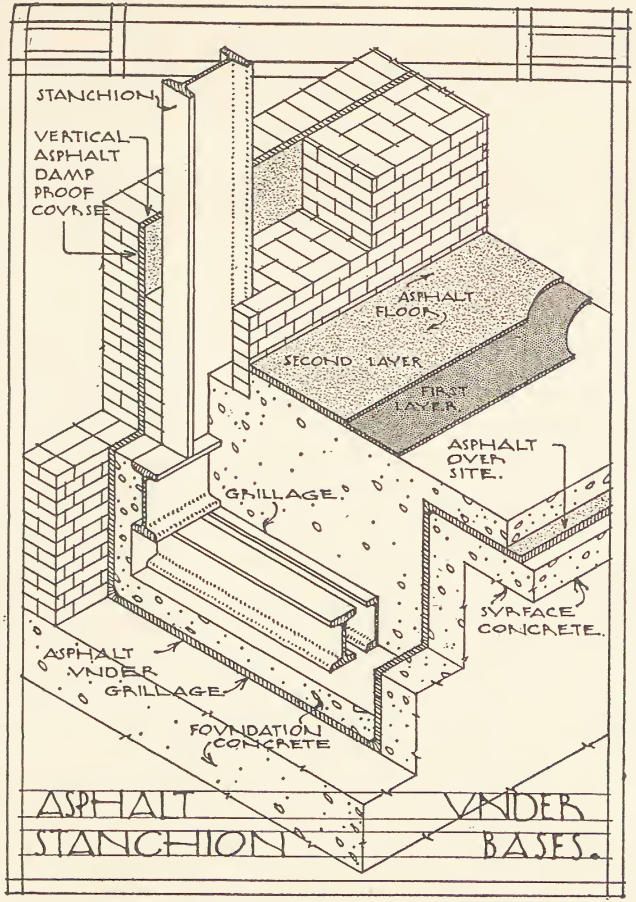


Fig. 20.—ASPHALTE UNDER STANCHION BASES
(By courtesy of the Limmer and Trinidad Lake Asphalt Co. Ltd.)

In country districts this should not be a difficult matter, but in more thickly populated areas there are certain limits according to the position of the site and the local conditions. Modern town-planning has done a great deal to overcome the crowding together of houses, and new estates are planned on much more hygienic principles than before ; the streets are arranged to give the maximum of free air circulation.

By-laws

There are statutory requirements governing the widths of streets, heights of buildings and the sufficiency of space to give ample circulation of air. The Ministry of Health Model By-laws, No. 4, deal with the amount of air space around buildings in Sections 52 and 53. The Housing and Town Planning, Model Clauses, 1935, and the London Building Act also deal with it.

Group Building

It would appear from this that the best class of building is one that is detached, but to erect all buildings on this principle would not be an economic or commercial proposition, whilst in many cases it would be impossible, especially in thickly populated areas. In the development of new estates, however, the practice of building in pairs, and small groups of four and six houses, has greatly enhanced the free movement of air around such buildings, thus leading to more healthy conditions.

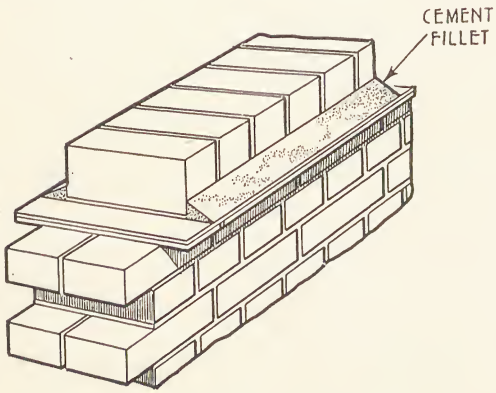


Fig. 21.—TILE CREASING

Flats and Office Buildings

In this respect, modern design and construction have made great strides to ensure that buildings of this type shall get the maximum of natural light and ventilation.

Dampness

This is a most important point and we have already dealt with one of the chief causes of dampness and its treatment by subsoil drainage, and the provision of a layer of site concrete. There are also many other causes of dampness and these will be dealt with and the remedies explained.

Damp-courses

Moisture will pass by capillary action from the soil into the walls of a building in spite of site concrete and concrete foundations. To prevent

this, horizontal and/or vertical damp-courses must be formed. In the case of a horizontal damp-course it should be formed below the level of the floor timbers and at least 6 in. above ground level (Fig. 10).

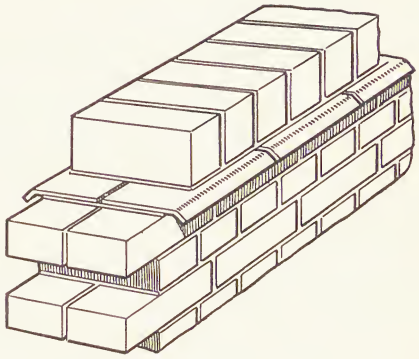


Fig. 22.—Drip tiles

Basement Damp-course

In the case of a basement room, the damp-course is a combination of the horizontal and vertical types, and is formed of a layer of mastic asphalte, which should be not less than ½ in. in thickness (Fig. 11).

Dry Areas

An alternative method of construction for basement walls to exclude dampness is to form what are termed dry areas, which may be of the open or closed type.

Fig. 12 shows a typical arrangement of an open area. The earthwork is supported by a retaining wall and the floor of the area arranged with a fall to a surface-water gully.

Figs. 13 and 14 show types of closed dry areas which are also referred to as air drains. It should be noted that in the construction of closed areas, provision must be made for ventilation and at the same time precautions taken to prevent the entry of vermin.

Semi-basement Floor

In the case of a floor which is only 2 ft. or 3 ft. below the outside ground level, the method shown in Fig. 15 has often been adopted to exclude the dampness. It will be seen that a complete basin is formed by the asphalte.

Materials for Damp-courses

Various materials are used for damp-courses, among which are the following :—

(1) Slates, laid in two courses in cement, with breaking joints.

(2) Bitumastic felt (made in rolls of 24 ft.).

(3) Salt-glazed perforated slabs (1½ in. and 2½ in. in thickness).

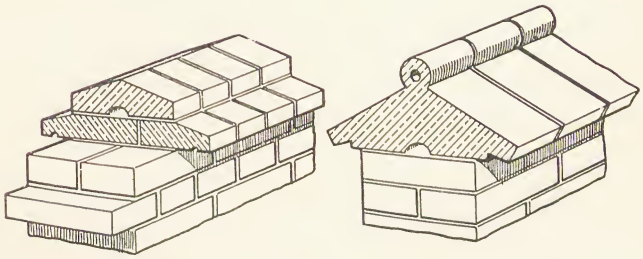


Fig. 23.—Moulded coping bricks

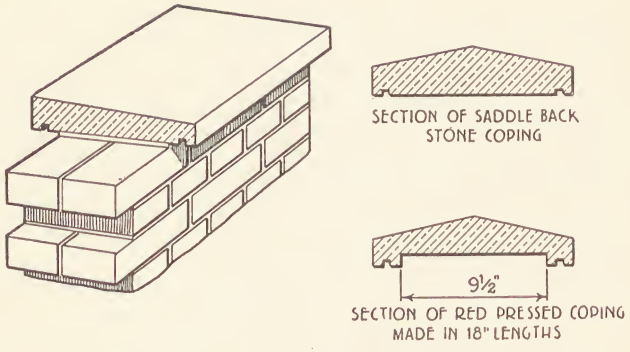


Fig. 24.—STONE AND PRESSED COPINGS

(4) Sheet lead (6 lb. or 7 lb. per foot super).

(5) Mastic asphalte (applied hot).

Deep Basements

Many of our modern buildings are now constructed with basements and sub-basements, calling for the effectual prevention of the entry of dampness. Asphalte in connection with waterproofed concrete is extensively used for this purpose and the construction is so arranged that a complete tank is provided. The illustrations, Figs. 17, 18, 19, 20, show very clearly the application of asphalte to damp-courses and basements.

Downward Dampness

Attention must be given to the precautions necessary for the prevention of dampness caused by rain-water soaking into parapet walls.

Various methods are adopted to form a " weathering " to the top of parapets, and these may be either :—

(1) Tile creasing (Fig. 21). (2) Drip-tile course (Fig. 22). (3) Moulded brick copings (Fig. 23). (4) Stone copings (Fig. 24).

Tile Creasing

This is simple but effective. Two courses of tiles are laid, breaking joint and bedded in cement. Over this is laid a course of bricks on edge, which also should be set in cement.

Drip-tile Course

These are laid singly with a brick-on-edge course above, all set in cement.

Moulded Coping Bricks

These are for the better class of work and form a good finish to parapet walls. They should be set in cement.

Stone Copings

These are specially shaped to throw off the water. They should be wide enough to project beyond the face of the brickwork at least $2\frac{1}{4}$ in. The under side should be " throated," i.e. grooved as shown in Fig. 24 to prevent the passage of water along the under side.

GENERAL PRINCIPLES OF HOT-WATER SUPPLY

IT is almost impossible to conceive a building being erected at the present time without provision being made for the supply of hot water for washing and other purposes. It is a matter which should have early attention in the design and construction of the building. Depending upon the type of building, it may be necessary to include heating or calorifier chambers, flues, gas pipes, or electric mains. If large cylinders or boilers are included in the installation, the builder must leave openings in the building fabric so that they can reach their ultimate position.

Two Types of Hot-water Supply

Broadly, hot-water supply systems may be divided into two types—storage and non-storage. The first is characterised by the storing of a considerable bulk of water which is warmed at a more or less constant rate. Hot water is drawn from this storage as and when required. Fig. 1 illustrates such a system.

The non-storage apparatus warms the water as and when it is required. Usually this type of apparatus does not supply the fittings in more than one room, and often each fitting has its own installation. The gas geyser is probably the most common example normally met.

The Main Difference between Storage and Non-storage Systems

Each type of installation has its own uses and advantages. There is one outstanding difference. The storage installation will supply hot water at a high discharge rate, but there is usually a limit to the amount which can be drawn. The non-storage installation normally gives a slow-running delivery, but can keep it up indefinitely. This rather suggests that where a quick flow is required for comparatively short periods at irregular intervals, it may be well to consider a storage apparatus ; on the other hand, where a supply is used more or less continuously, a non-storage system might be adopted.

Other Factors Governing the Choice of System

These are not the only factors, however. The presence, or absence, of peak loads, what type of fuel or energy is available and its costs, whether the building exists or is under construction—all these play a part in determining the most suitable installation. Some little time,

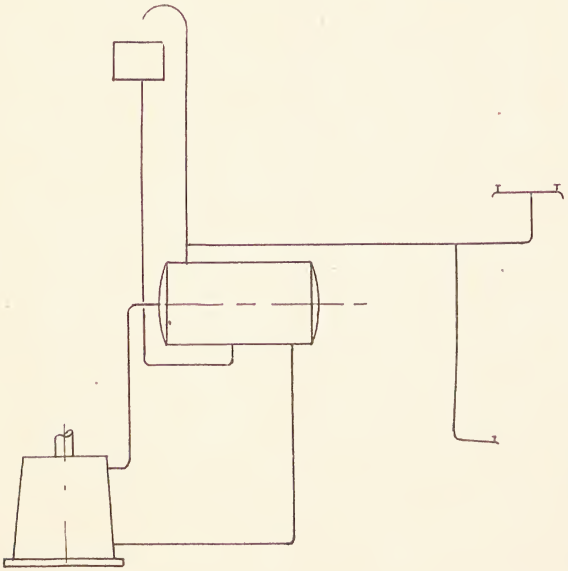


Fig. 1.—TYPICAL STORAGE INSTALLATION

therefore, should be given to consideration of these matters, particularly if the building, or its locality, is at all unusual.

The Requirements of a Satisfactory Hot-water Supply Installation

It may be well to outline briefly the essential requirements from, and components of, a satisfactory hot-water supply installation. The requirements are five in number. Firstly, hot water must flow from each tap at the desired rate. Secondly, the opening of the various taps should influence as little as possible the delivery from taps already in use. Thirdly, not always of prime importance, it should not be necessary to run off any large quantity of cold water before hot water is obtained. Fourthly, the water should be at a high enough temperature to serve the purpose for which it is to be used. Fifthly, the quantity of water available must be sufficient.

These requirements are essential. There are other points which also require thought. The water should be heated at the lowest cost. All things being equal, the apparatus should be as cheap as possible. The amount of heat wasted should be reduced to the least possible. Hot-water supply systems often include towel rails or coils in cupboards, etc.; in such cases, the circulation of hot water to and from the towel rails, or coils, must be satisfactory.

Components of a Hot-water Supply Installation

The attainment of these desiderata is dealt with later. In order to obtain a complete understanding of the problem to be solved, the necessary components of hot-water supply installations may be indicated.

Piping

Common to every type of apparatus are a source of cold water and a means of heating it. A system of piping is required to lead the cold water to the heating element. Some means is required to control the generation of heat. Sometimes the delivery tap is fixed directly to the

vessel containing the heating element; no other apparatus, except that already mentioned, is then necessary. This applies to a normal gas geyser or local electric installation, such as is shown in Fig. 2.

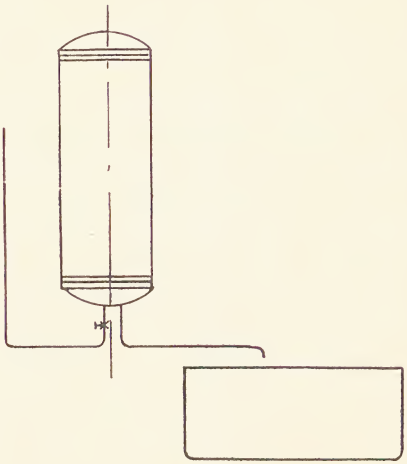


Fig. 2.—LOCAL ELECTRIC INSTALLATION

Storage Tank

With a storage installation, a vessel may be provided to store the water while it is heated; this must be connected to the heat generator by a system of pipes. A more or less complex network of pipes must also be run from the storage vessel to the taps. Valves must be provided to control and isolate portions of the installation as necessary. The apparatus must be perfectly safe. This last requirement necessitates various fittings, depending upon the type of installation.

Non-storage Apparatus

There are only two types of non-storage apparatus in general use: the gas geyser, and the instantaneous steam water-heater. The latter would only be applied where a supply of steam already exists, and so is normally found nowhere but in ships and factories. The gas geyser has the one considerable advantage that it is easily arranged so that each consumer pays for his own hot water directly. A few electric geysers have been fixed in this country, but their use is not extensive. This is due to the extremely large current drawn at irregular intervals and probably for short periods, forming an uneconomical load for the supply company.

The Storage Installation

The storage installation is now used in the majority of cases, even the smallest house property having its independent boiler. It is almost always the cheapest method of obtaining a constant supply of hot water. Also, it causes probably less disfigurement to the house than any other method.

A Typical Installation in a Small House

A pictorial view of the type of apparatus now found in thousands of houses is given in Fig. 3. It employs a small independent boiler, usually fixed in the kitchen.

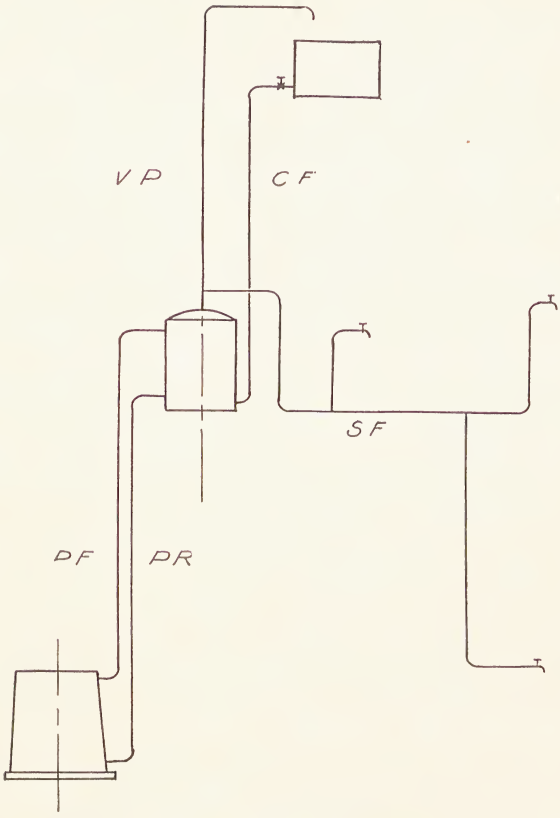


Fig. 3.—TYPICAL HOUSE INSTALLATION

PF, primary flow; PR, primary return; SF, secondary flow; VP, vent pipe; CF, cold-water supply pipe.

The Primary Flow

Hot water heated in the boiler ascends through the flow pipe (PF) to the storage, usually fixed in the linen cupboard. A return pipe (PR) takes the cooler water from the tank back to the boiler. These pipes, connecting the boiler and storage vessel, are usually called the "primary" flow and return.

The Secondary Flow

From the top of the tank a pipe (SF) is taken to lead the hot water to the taps; this is the "secondary" flow pipe, and in the present example there is no "secondary" return. A vent pipe (VP), taken off the highest part of the secondary flow, releases air from the system. A cold-water supply pipe (CF) brings cold water from the cold-water tank to the bottom of the storage tank.

The Boiler

The apparatus shown supplies one bath, one basin, and one sink. A suitable boiler would be rated at about 20,000 B.Th.U. per hour; a B.Th.U. is, of course, the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. A gallon of water weighs ten pounds, and to raise its temperature 100° Fahrenheit will require $10 \times 100 = 1{,}000$ B.Th.U. This is a convenient factor to remember. If the last three figures are "knocked off" a B.Th.U. boiler rating, it will give the number of gallons of water heated through 100° Fahrenheit per hour; 100° Fahrenheit is the temperature rise normally required.

The present boiler would therefore heat 20 gal. per hour. This

output would usually be too much, as hot water will not be consumed at such a rate. To obtain this output, however, the boiler must be well attended to; this will not be the case during the greater part of the day, and so the output will be satisfactory.

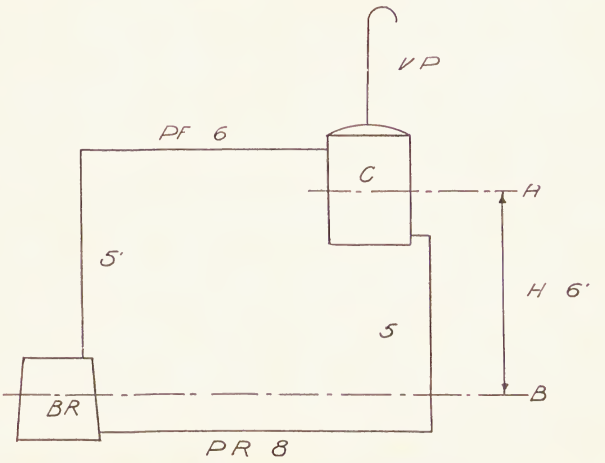


Fig. 4.—DIAGRAM FOR CALCULATION OF PRIMARY CIRCUIT
BR, boiler; C, cylinder; PF, primary flow; PR, primary return; VP, vent pipe.

Sizes of Pipes

The boiler is obtainable in several kinds of enamel finish, and so does not detract from the appearance of the kitchen. The primary flow and return should not be less than $\frac{3}{4}$ in. in diameter, and preferably 1 in. These pipes should rise all the way from boiler to cylinder, in order to prevent the collection of any air. The boiler should be fitted with a thermometer, safety-valve, and an emptying cock. These fittings are often omitted on these small installations: a very unwise proceeding. The thermometer helps to prevent over-heating; the safety-valve avoids danger in frosty weather, and the drain cock enables the system to be emptied without difficulty.

Connection to the Storage Vessel

The storage vessel may take the form of either a closed-top tank, or a cylinder. In either case, it should be fitted with a man-hole and flanges for the pipe connections. The thickness should not be less than $\frac{1}{8}$ in. The capacity should be at least 30 gal. Often 20-gal. tanks are fitted, but these are not large enough to enable two baths to be taken in quick succession when required.

Secondary Piping

The secondary piping should be as shown. It should rise to a high point, to relieve air from the apparatus, and then fall to the various taps. The diameter should be 1 in. until the bath is reached, with $\frac{1}{2}$-in. connection to the basin and $\frac{3}{4}$-in. to the sink. The cold-water supply pipe should be 1 in. in diameter, and fitted with a control valve to shut off the supply; it should be joined near the bottom of the tank, or cylinder. The primary flow and return should connect near the top and bottom respectively, and the secondary should be taken off the top.

FIRST PRINCIPLES OF HOT-WATER INSTALLATIONS

The installation described is as small and simple as could well be, yet the details to be watched are quite impressive. These details may all be settled from first principles. It will be of advantage to study these principles as deeply as is necessary, to determine that any given apparatus has been designed in accordance with them.

Design of Storage-type Installation

When the advantages and disadvantages of various types of equipment come to be discussed, a knowledge of the theory behind their purpose will render judgment sounder. The design of a storage-type installation may be divided into five parts : the determination of the storage capacity, the power of the boiler or other heater, the diameter of the pipes to deliver the requisite quantity of water at the taps, the diameter of the circulation pipes to maintain a proper circulation, and the thickness of the plates of cylinders, etc.

There are two circulations to be considered. Firstly, the circulation of water from the boiler to the cylinder, or tank—the primary circulation ; and secondly, the circulation from the cylinder, or tank, through the building—the secondary circulation. The first is not a difficult calculation. The second is more complicated, but, if properly done, gives satisfactory results not normally obtained without the calculations. It may be mentioned here that it is possible after considerable experience to guess at pipe sizes and rely on regulation by valves to ensure satisfactory circulations. This is more expensive than proper calculations, and there is always a possibility of complete failure.

Fig. 4 represents an elementary system comprising boiler (B), storage cylinder (C), and primary flow and return pipes, (PF) and (PR), connecting them. The vent pipe (VP) and cold-water supply pipe (CF) play no part in the circulating process, and are included merely to complete the apparatus.

The Heating Process

When the fire is lighted in the boiler the flow pipe gradually becomes warm, and eventually the cylinder and return pipe. The temperature continuously increases, and if the boiler maintains its full output, and no water is drawn, the system eventually boils. Normally, of course, this never happens, as cold water enters the cylinder due to hot water being drawn from a tap. The circulation never attains a constant state, but the action is clear. The water in the boiler, being warmed, has its density decreased. The water in the cylinder, being cooler, is heavier per cubic foot, and so sinks and pushes the warmer water out of the boiler.

This process is continuous so long as the water in the cylinder is cooler than that in the boiler. The heavier column, consisting of the cylinder and the vertical pipe from it, overbalances the lighter column comprising

the boiler and the pipe rising from it. This constitutes a circulating pressure which must be absorbed by the friction of the water flowing through the system. The velocity of the water can be varied as desired by altering the sizes of the pipes.

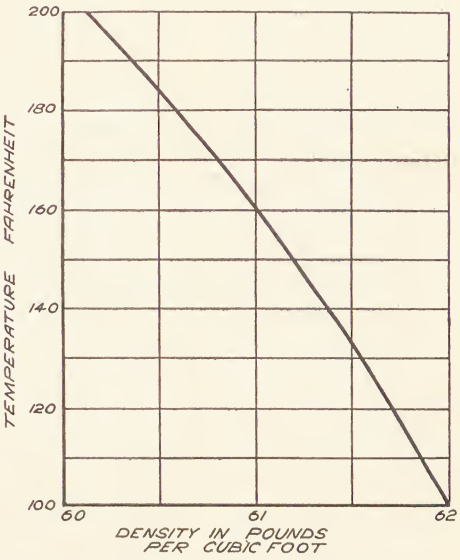


Fig. 5.—CHART SHOWING DENSITY OF WATER AT VARIOUS TEMPERATURES

How to Determine the Value of the Circulating Pressure

The value of the circulating pressure may be arrived at from the densities of the water in rising and falling columns. Let the water in the falling column have a density of D_1 lb. per cu. ft., then for each foot in height there will be pressure at the bottom of the column of D_1 lb. per sq. ft.; similarly for the rising column—if the water has a density of D_2 lb. per cu. ft., there will be a pressure at the bottom of D_2 lb. per sq. ft. for each foot height. The difference between these two pressures, that is, $D_1 - D_2$, gives the circulating pressure in lb. per sq. ft. for each foot in height.

If the height of the circulation is H ft., the total circulating pressure will be H $(D_1 - D_2)$ lb. per sq. ft. The circulation height may be taken as the vertical distance between the lines A and B in Fig. 4. Line A is midway between the connections on the cylinder, and line B midway between the connections on the boiler. It is to be noticed that if the flow and return connections are practically at the bottom of the cylinder, as is sometimes the case, the circulating pressure would be reduced, as line A would be lowered to correspond to the mid point of the connections.

The density of water at various temperatures is given on the chart in Fig. 5. It is not possible to determine on fixed flow and return temperatures, as these will continually vary with the varying demands for hot water. This is not of great moment. If the system is properly designed for given conditions, the circulation will be quite satisfactory and proportionate at higher or lower temperatures.

Suitable Temperatures for Normal Conditions

Suitable temperatures for normal conditions are 165° Fahr. flow, and 135° Fahr. return, giving a difference of 30° and a mean of 150° Fahr. Referring to Fig. 5, water at 135° Fahr. has a density of

61·46 lb. per cu. ft., and at 165° Fahr. 60·89 lb. per cu. ft. The difference is 0·57. If the height H in Fig. 4 is 5 ft., the total pressure available to maintain the circulation is $0{\cdot}57 \times 5 = 2{\cdot}85$ lb. per sq. ft. This pressure must be absorbed by friction of the water flowing through the pipes if design conditions are to be attained.

Calculating the Weight of Water in Pipes

The weight of water flowing through the pipes next demands attention. To obtain this, the maximum output of the boiler must be known. Let it be assumed that this is 120,000 B.Th.U. per hour. Each pound of water flowing from the boiler will deliver 30 B.Th.U. with 30° Fahr. temperature drop. With a boiler rating of 120,000 B.Th.U. the weight of water to be circulated per hour is 120,000 divided by 30, which is equal to 4,000 lb.

Pressure Drop per Foot of Pipe

This is one factor affecting the pipe diameters, the second being the allowable pressure drop per foot of pipe. The lengths of the various pipes are indicated on Fig. 4, and if these are totalled it will be found that they amount to 24 ft. The water has also to flow round elbows and tees and through valves, and the flow is subject to sudden changes of velocity where the water enters or leaves the boiler and cylinder. These factors all retard the flow. The exact effect on the circulation varies with the diameter of the pipe. This latter is not yet known, so an approximation must be made.

Retardation Due to Elbows, Tees, etc.

Let it be assumed that the retardation due to elbows, tees, etc., will be equal to adding 100 per cent. to the length of the circuit. This then becomes 48 ft. instead of 24 ft. It has already been found that the total available pressure for the circulation is 2·85 lb. per sq. ft. The pressure available per foot then becomes 2·85 divided by 48, which is about 0·06.

Pressure Absorbed by Friction

The chart given as Fig. 6 shows the pressure absorbed in friction by a foot of pipe when carrying various weights of water per hour. In the present instance the pipe must carry 4,000 lb. per hour; the allowable pressure drop per foot is 0·06 lb. per sq. ft. Referring to the side of the chart at the pressure drop of 0·06, and proceeding across the chart, it is found that a 2½-in. pipe will carry 4,600 lb., and so is slightly too big. A 2-in. pipe will only carry 2,600 lb., and so is much too small.

TABLE I

FACTORS FOR FITTINGS

Elbow	2	Return Bend	3
Bend	1	Gate Valve	1
Obtuse Elbow	1	Angle Valve	3
Tee Branch	2–4	Globe Valve	8
Reducer	2–4	Radiator, Tank, or Cylinder	4

The 2½-in. pipe may be adopted, but it is well to check the actual resistance of the elbows, valves, etc. Table I gives constants for various fittings, which, when multiplied by the diameter of the pipe in inches, give an equivalent length in feet of the pipe which offers the same resistance.

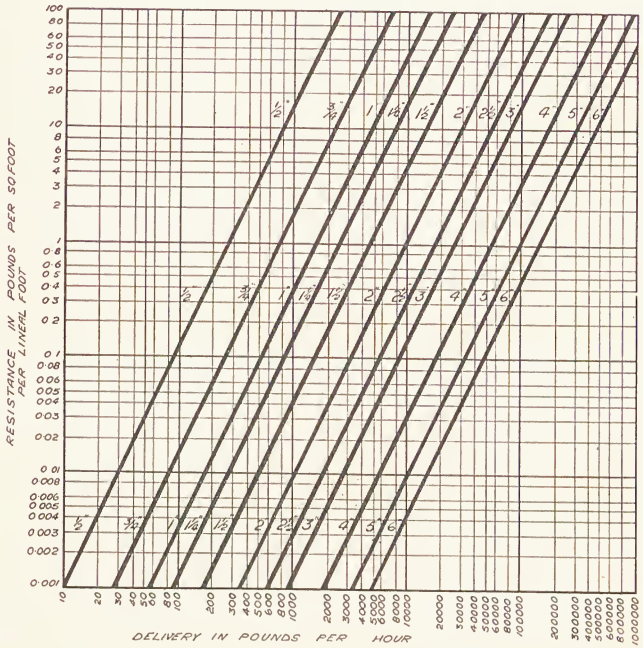


Fig. 6.—CHART SHOWING PRESSURE ABSORBED BY FRICTION BY A FOOT OF PIPE CARRYING VARIOUS WEIGHTS OF WATER PER HOUR

Consider a typical circuit consisting of the following fittings:—two elbows, one tee, connections to the boiler (6 ft.) and to the cylinder (6 ft.). Summarising their constants as follows, and multiplying them by 2½, the diameter of the pipe, the total equivalent length is 45 feet.

2 elbows	$= 2 \times 2 \times 2\frac{1}{2}$ . . .	$= 10$
1 tee	$= 1 \times 2 \times 2\frac{1}{2}$ . . .	$= 5$
1 connection to boiler	$= 1 \times 6 \times 2\frac{1}{2}$	$= 15$
1 connection to cylinder	$= 1 \times 6 \times 2\frac{1}{2}$	$= 15$
		45

As only 24 ft. was allowed in arriving at the diameter of 2½ in., it will be well to check this size. The total length of the circuit becomes 24 + 45 = 69 ft. Referring again to the chart, Fig. 6, it will be found that the 4,000-lb. line intersects the 2½-in. pipe line at 0·046. The exact pressure drop per foot of pipe is then 0·046 lb. per sq. ft. The total friction loss becomes 0·046 × 69 = 3·17 lb. per sq. ft. This is 0·31 lb. per sq. ft. more than the available circulating pressure of 2·85 lb. per sq. ft. If the circulation were one of a complex network this would not be a sufficiently close balance. However, as the system cannot react on any other circulation the pipe diameter may stand. In practice

the installation will work with a temperature drop of about 33° Fahr. instead of the 30° Fahr. originally chosen.

The calculation of any similar simple circuit may be made in the same manner. Complex circuits are similar in principle, but the calculations are somewhat more complicated.

Secondary Circulation Calculations

Secondary circulations in a hot-water supply apparatus are probably as complicated a problem as is normally met with in pipe sizing, but satisfactory results can be obtained. It must always be borne in mind that the cooler water in any particular circuit creates the circulating pressure and this pressure must be absorbed in friction.

Up-feed System

In general, secondary circulations may be divided into two types, up-feed and down-feed. A typical up-feed system is shown in Fig. 7. Flow and return mains are taken from the cylinder and run horizontally in the building, usually at high level in the basement. Flow and return risers are taken from the mains and run up through the building in convenient positions, positions near the taps being best. It will be noticed that the secondary return risers are joined to the flow riser below the top floor. If the top fitting does not have a long horizontal run, this is quite satisfactory.

Down-feed System

Fig. 8 shows a down-feed system. Here the flow main is taken from the cylinder and run to the top of the building. It then distributes horizontally and serves drop pipes, from which connections to the fittings are taken. The drop pipes continue down to the basement and are joined to a return main. This main eventually reconnects to the cylinder.

The advantages and disadvantages of each type of installation will be discussed later. Meanwhile, it should be noted that the size of the flow pipe will always have a certain minimum depending on the flow of water required from the taps. This will also apply to the return pipe if taps are supplied from it.

Calculations for an Up-feed System

The simple installation shown in Fig. 9 may be used to illustrate the calculation of an up-feed system. The principles are similar to those employed for Fig. 4. The difficulties are obtaining the weight of water flowing and the circulating pressure. The flow pipe is shown as $1\frac{1}{4}$ in., this being determined by the flow from the taps. It may be assumed, as a starting-point, that probably $\frac{3}{4}$-in. pipe will be suitable for the return.

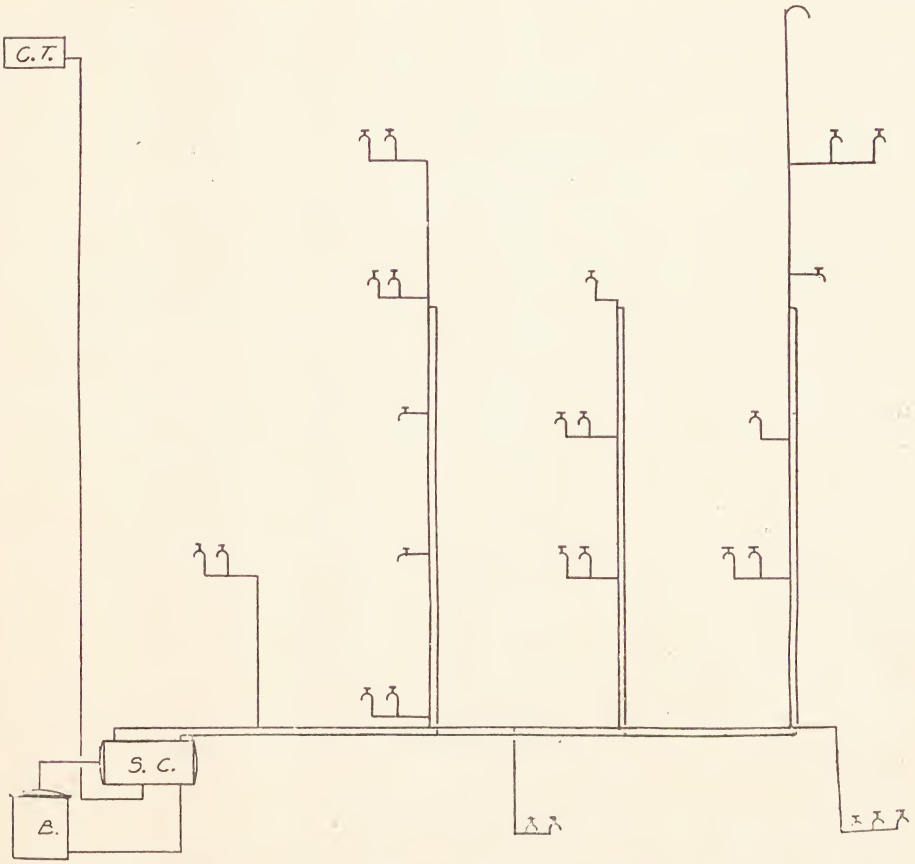


Fig. 7.—A TYPICAL UP-FEED SYSTEM
B, boiler; SC, storage cylinder; CT, cold-water tank.

Heat Loss from Pipes

The total length of $1\frac{1}{4}$-in. pipe actually forming part of the circulation is 1 ft. + 30 ft. + 20 ft. = 51 ft. The $\frac{3}{4}$-in. return amounts to 2 ft. + 30 ft. + 20 ft. = 52 ft. Table II shows the heat loss from one foot of bare pipe with the normal temperature of water obtaining in a hot-water

TABLE II

HEAT LOSS FROM 1 FT. OF BARE PIPE

	B.Th.U. per hour		*B.Th.U. per hour*
$\frac{1}{2}$ in.	45	$2\frac{1}{2}$ in.	125
$\frac{3}{4}$ in.	60	3 in.	150
1 in.	65	4 in.	190
$1\frac{1}{4}$ in.	80	5 in.	250
$1\frac{1}{2}$ in.	90	6 in.	270
2 in.	110		

supply installation. From this it is seen that $1\frac{1}{4}$-in. pipe emits 80 and $\frac{3}{4}$-in. pipe 60 B.Th.U. per foot. The total heat loss from the pipes is then as set out in tabular form below :—

$$51 \times 80 = 4{,}080$$
$$52 \times 60 = 3{,}120$$

7,200 B.Th.U. per hour.

Temperature Drop

Now the temperature drop desired between the flow and return at the cylinder must be settled. Unless it is desired for some particular reason that the temperature drop between the cylinder and taps be small, it is well to adopt for trial purposes a temperature drop of 30° Fahr. A smaller drop means a more expensive installation, and also involves higher running costs due to increased heat losses from the pipes.

Weight of Water

Adopting 30° Fahr. for the present installation, the weight of water flowing through the pipes can at once be found. Each pound will give off 30 B.Th.U. in cooling through 30° Fahr., so that the weight of water flowing through per hour will be 7,200 ÷ 30 = 240 lb.

Circulating Pressure

Next the circulating pressure must be calculated. This, as before, is the difference in pressure created by the differing densities of a cool falling column and a warm rising column. The former comprises the

TABLE III

TEMPERATURE DROP IN PIPES IN ° FAHR. PER FOOT OF BARE PIPE

Weight of water, lb. per hour	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	4 in.
100	0·45	0·6	0·65	0·8	0·9	1·1	1·25	1·5	1·9
120	0·38	0·5	0·54	0·62	0·75	0·92	1·04	1·21	1·58
140	0·32	0·43	0·46	0·57	0·64	0·79	0·89	1·07	1·36
160	0·28	0·37	0·41	0·5	0·56	0·69	0·78	0·94	1·19
180	0·25	0·33	0·36	0·44	0·5	0·61	0·69	0·83	1·06
200	0·22	0·3	0·33	0·4	0·45	0·55	0·63	0·75	0·95
250	0·18	0·24	0·26	0·32	0·36	0·44	0·5	0·6	0·76
300	0·15	0·2	0·22	0·27	0·3	0·37	0·42	0·5	0·63
350	0·13	0·17	0·19	0·23	0·26	0·31	0·36	0·43	0·54
400	0·11	0·15	0·165	0·2	0·225	0·275	0·315	0·375	0·475
450	0·1	0·133	0·14	0·177	0·2	0·244	0·277	0·33	0·422
500	0·09	0·12	0·13	0·16	0·18	0·22	0·25	0·3	0·38
600	0·075	0·1	0·11	0·135	0·15	0·185	0·21	0·25	0·365
700	0·065	0·085	0·095	0·125	0·13	0·155	0·18	0·215	0·27
800	0·055	0·075	0·083	0·1	0·113	0·138	0·158	0·189	0·238
900	0·05	0·066	0·07	0·089	0·1	0·122	0·139	0·165	0·211
1000	0·045	0·060	0·065	0·08	0·09	0·11	0·125	0·15	0·19

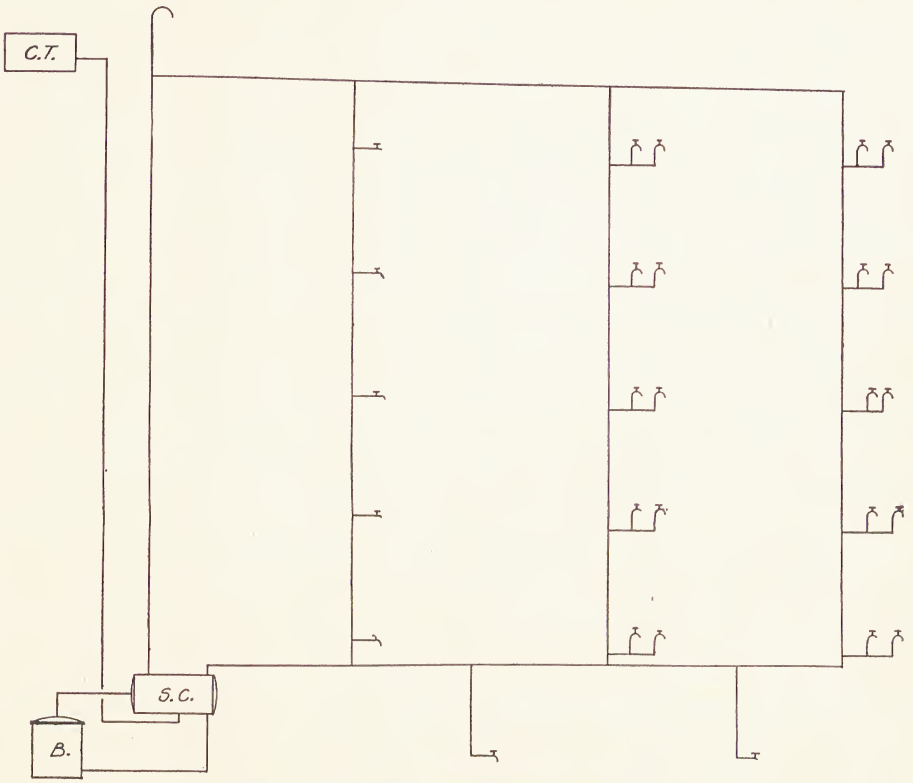


Fig. 8.—TYPICAL DOWN-FEED SYSTEM
B, boiler; SC, storage cylinder; CT, cold-water tank.

20-ft. vertical return riser and the 2-ft. vertical return at the cylinder. The rising column is the top 1 ft. of the cylinder, the 1-ft. riser from the cylinder, and the 20-ft. vertical flow riser at the end of the circulation. Where the rise at the cylinder is short compared with the risers in the building, as in the present example, it may be ignored. The circulating pressure then will be created by the two columns 20 ft. high, at average temperatures to be determined.

The average temperature may be taken as that at the mid point of each riser. It may also be assumed with sufficient accuracy that for each degree Fahrenheit the water cools, its density increases by 0·02 lb. per cu. ft. If, then, the difference in temperature between the mid points of the rising and falling columns is found, it may be multiplied by 0·02 to give a near approximation of the difference in average density of the two columns. When this is multiplied by the total height of the risers it will give the circulating pressure in pounds per square foot.

Consulting Table III, it will be found that when $1\frac{1}{4}$-in. pipe is carrying

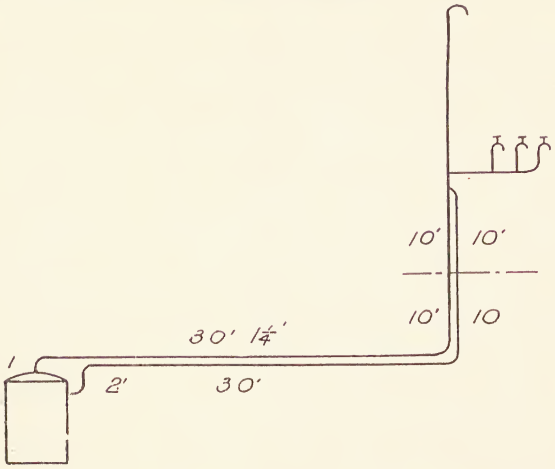


Fig. 9.—DIAGRAM FOR CALCULATION OF SECONDARY CIRCULATION

240 lb. of water per hour it cools 0·33° Fahr. for each foot; with ¾-in. pipe the water cools 0·25° Fahr. for each foot. It is 10 ft. from the mid point of the flow riser to the top of the circulation, so the water will cool 10 × 0·33 = 3·3° Fahr. In the 10 ft. from the top of the circulation to the mid point of the return riser, it will cool 10 × 0·25 = 2·5° Fahr. The total difference in average density will be 5·8 × 0·02 = 0·116 lb. per cu. ft. The height of the circulation being 20 ft., the circulating pressure will be 0·116 × 20 = 2·32 lb. per sq. ft.

Resistance Created by Friction

Now the resistance created by friction in pipes must be found. The flow pipe has two elbows in it, each having a factor of 2. Their equivalent length is 2 × 2 × 1¼ = 5 ft. The length of the flow pipe is 51 + 5 = 56 ft. Referring to the chart, Fig. 6, it is found that with 1¼-in. pipe carrying 240 lb., the pressure drop is 0·007 lb. per sq. ft. The total pressure drop in the flow main will then be 56 × 0·007 = 0·39 lb. per sq. ft.

The return main has one tee, four elbows, and one cylinder connection. Their equivalent length is 12 ft., as tabulated below:

1 tee	1 × 2 × ¾ =	1½
4 elbows	4 × 2 × ¾ =	6
cylinder	1 × 6 × ¾ =	4½
		12

The pipe length is 52 ft., making a total of 64 ft. Again referring to the chart, Fig. 6, it is found that 240 lb. carried by a ¾-in. pipe means a pressure drop of 0·085 lb. per sq. ft. for each lineal foot. The total pressure drop in the return main will be 64 × 0·085 = 6·4 lb. per sq. ft.

The total pressure loss in the circulation will be 0·39 + 6·4 = 6·79 lb. per sq. ft. against the circulating pressure of 2·34 lb. per sq. ft. The apparatus will not work with a 30° Fahr. temperature drop with a

$\frac{3}{4}$-in. return. From the data brought forward during the calculations, it is probable that a $1\frac{1}{4}$-in. return would be required. This is hardly worth while, and it is interesting to find approximately with what temperature drop the system will work.

The circulating pressure will increase approximately proportional to the temperature drop, and the friction will decrease inversely as the square of the temperature drop. An increase of 30° Fahr., to 40° Fahr., may be tried. The circulating pressure will become $2{\cdot}32 \times \frac{40}{30}$ = 3·1 lb. per sq. ft. The friction will decrease to $7{\cdot}13 \times (30/40)^2$ = 4 lb. per sq. ft. These are quite close. Taking into account the extra circulating pressure due to the falling column at the cylinder, the system will work with about 40° Fahr. temperature drop. This would be quite satisfactory for the average installation.

QUESTIONS AND ANSWERS

What are the two main systems of Hot-water Supply ?

Storage and non-storage systems.

What is the main difference between these two systems ?

The storage installation will supply hot water at a high discharge rate, but there is usually a limit to the amount which can be drawn. The non-storage installation normally gives a slow-running delivery, but can keep it up indefinitely.

What are the five requirements of a satisfactory Hot-water Supply Installation ?

(1) Hot water must flow from each tap at the desired rate.

(2) The opening of the various taps should influence as little as possible the delivery from taps already in use.

(3) It should not be necessary to run off any large quantity of cold water before hot water is obtained.

(4) The water should be at a high enough temperature to serve the purpose for which it is to be used.

(5) The quantity of water available must be sufficient.

What are the essentials of a Storage Installation ?

A vessel to store the water while it is heated, which must be connected to the heat generator by a system of pipes. A more or less complex network of pipes must also be run from the storage vessel to the taps. Valves must be provided to control and isolate portions of the installation as necessary.

What types of Non-storage Apparatus are in general use ?

The gas geyser and the instantaneous steam water-heater, and the electric geyser.

What is meant by Primary Flow ?

Hot water heated in the boiler ascends through the flow pipe to the storage tank and back through a return pipe to the boiler. These pipes connecting the boiler and storage vessel are usually called the primary flow and return.

What is meant by the Secondary Flow ?

This is the system of pipes which lead the hot water from the tank to the taps and also includes the cold-water feed from the cistern to the bottom of the hot-water storage tank.

What is meant by an Up-feed System ?

The flow and return mains are taken from the cylinder and run horizontally in the building, usually at high level in the basement. Flow and return risers are taken from the mains and run up through the building in convenient positions.

What is meant by a Down-feed System ?

The flow main is taken from the cylinder and run to the top of the building. It then distributes horizontally and serves drop pipes, from which connections to the fittings are taken. The drop pipes continue down to the basement and are joined to a return main, which eventually reconnects to the cylinder.

Where should the Secondary Return be joined to the Storage Vessel ?

As close to the top as possible.

Why is this ?

As water is drawn off by the return pipe as well as by the flow, this provision is to ensure that the hottest available water is drawn off by the return as well as by the flow.

SANITARY SURVEYING

PART II.—TESTING VERTICAL STACKS

WE will now discuss the methods of testing the vertical stacks of pipe which enter the drain direct, i.e. without the discharges passing through a gully trap.

" One-pipe " System

Prior to 1930, this had reference only to soil pipes, but since that date the Ministry of Health formulated model by-laws for local authorities to adopt, whereby waste pipes as well as soil pipes could discharge into the drain without the interposition of a gully trap. This principle of drainage was accepted by the London County Council, and is embodied in their latest By-laws, and practised by all the London Boroughs. It would be well to add that there are certain regulations governing this practice, which must be strictly adhered to. The principle is known in the trade as the " one-pipe " system, and will be dealt with fully in a later article.

Extra Precaution Necessary

It is to these stacks which enter the drain direct that special attention must be given, owing to the fact that the air passing through them is direct from the drain, and may be charged with micro-organisms ; in addition, the vertical stacks or branch waste pipes may pass through a room used for human habitation.

It is, therefore, necessary that such a test should be applied to these pipes as will reveal the fact as to their soundness or otherwise, and it is common practice to obtain this result by means of the air test.

Air Test or Pneumatic Test Applied to Cast-iron Soil Pipe

The air-testing apparatus as shown in Fig. 1 consists of a glass U-shape tube fixed into a metal case with graduations marked from zero, which is situated in the centre of its height ; a $\frac{1}{2}$-in. rubber tube about 3 ft. long and a disc plug according to the size of the soil or waste pipe.

To apply the test, the branch drain from the vertical stack must be stopped off with an expanding rubber stopper or air bag stopper, and a quantity of water discharged behind it to ensure that the stopper is sound, making sure that the seals of all the traps connected to the stack are fully charged. The head of the vertical stack has been selected to

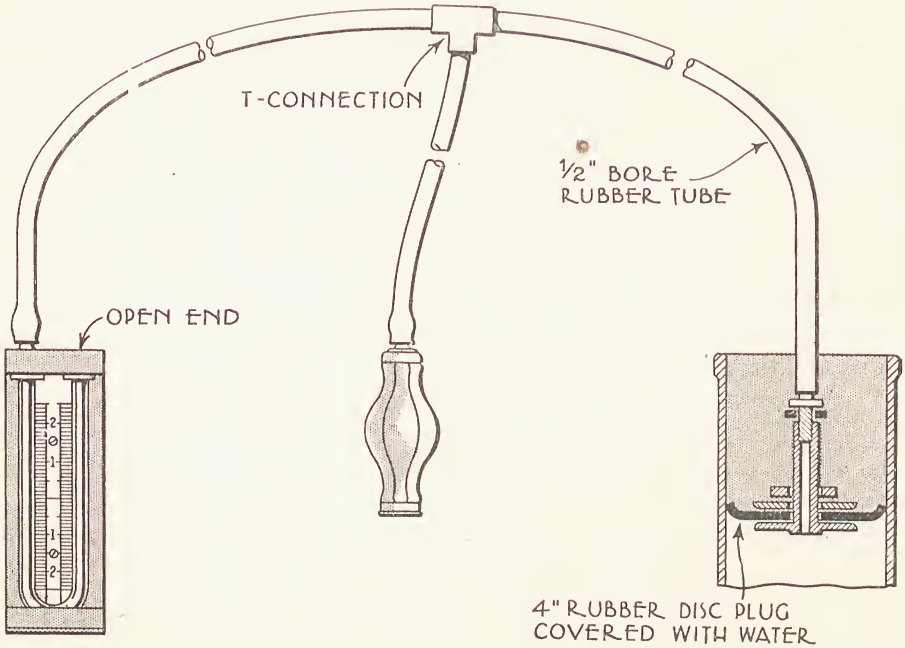


Fig. 1.—THE TESTING APPARATUS REQUIRED FOR AN AIR TEST OR PNEUMATIC TEST APPLIED TO A CAST-IRON SOIL PIPE

Left, Glass U-shaped tube; centre, hand bellows for forcing air into the stack via the rubber tube; right, disc plug inserted in vertical stack.

apply the test, into which we insert a disc plug which has a nipple to which we connect one end of the rubber tube; this should also be covered with water, as shown.

After forcing air into the stack via the rubber tube, either by blowing from the mouth, or by using a hand bellows which can be fixed to the rubber tube by a tee connection, the other end of the tube is slipped on to the glass nipple of the U-tube. The extra pressure of air forced into the stack should cause the water in the U-tube gauge to be depressed on the rubber tube side, and rise up in the other side to the same amount.

If the stack is sound, then the water will remain at this level, but should there be a defect in any of the pipes, joints, or connections, the water in the gauge will return to its original level. The test, therefore, is a sure one. To assist in tracing the defects, a little soapy water applied around the joints will reveal any defects by the formation of bubbles. If the joints are sound it is a good plan to apply a smoke test, which may reveal a " blow-hole " or " sand-hole " in some part of the vertical cast piping.

Amount of Pressure Applied

The air test is desirable where new work is involved, and although the amount of pressure applied is very small, the test is reliable. The depth of the water seal of the trap is the governing factor as to the amount of pressure that can be applied. The water seal of an ordinary closet trap being 2 in. in depth, it will readily be seen that if the water in the trap is depressed by the air pressure more than 2 in., the air will escape into the closet apartment.

The water area on the inlet side of the closet being larger than on the outlet, the water will not rise to more than half the amount to that depressed (Fig. 2), therefore we get an air pressure equal to 3 in. of water, which represents approximately ·108 lb. per square inch, calculated as follows: ·434 = lb. pressure on the square inch for one foot head of water; 3 in. being one-fourth of a foot, ·434 ÷ 4 = ·108 lb. It will be noted that the air test can be applied only to vertical stacks where a manhole is provided for inserting a stopper in the branch drain, and is therefore only adaptable to drains of modern construction.

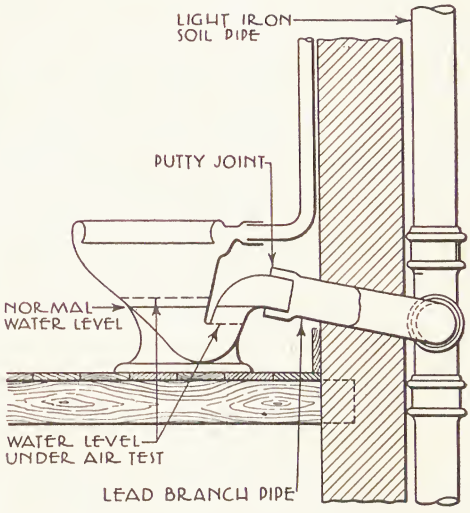


Fig. 2.—As the water area on the inlet side of the closet is larger than on the outlet, the water will not rise to more than half the amount to that depressed

Smoke Test to Soil Pipe

Sometimes a test has to be applied to soil pipes connected to old drainage systems, i.e. those which have no manholes, and are connected to the drain by means of junctions. Under these conditions an air test is not practicable; but a smoke test can be applied via the drain to which the soil pipe is connected; in fact, drains are usually tested at the same time. (The smoke test on the drain was dealt with fully in

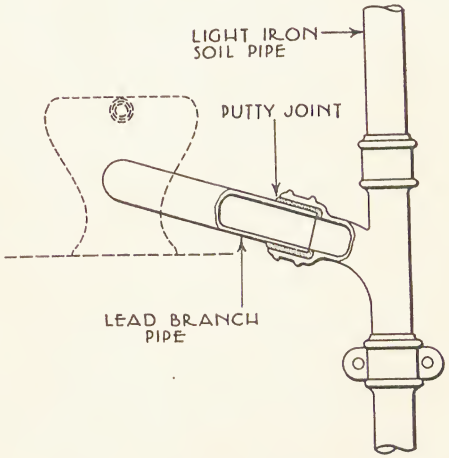


Fig. 3.—A possible defect

Defective putty at the joint between lead pipe and soil pipe may cause leakage.

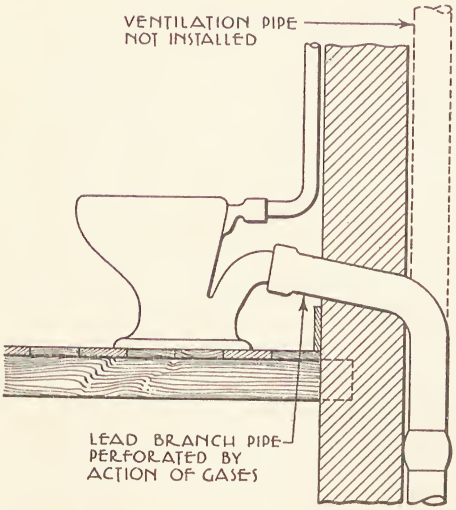


Fig. 4.—AN UNUSUAL FAULT, DUE TO LACK OF VENTILATION PIPE

The lead branch taking the closet discharge was eaten through by gases retained in the branch.

the previous article). In making your observation as to the soundness of the soil pipe, the doors, windows, and permanent ventilators of the W.C. apartments should be closed, so as to retain any smoke which may escape from the connections of the closets to the soil branches or from the soil pipe itself, if such is fixed inside the house (very often in a brick chase), as is the case in many old town and country houses.

After a good volume of smoke has passed out of the head of the soil pipe, the latter should be plugged off, and the smoke machine steadily pumped so as to maintain a slight pressure; whilst the assistant is operating the machine, carefully examine the exposed pipes and joints, entering each apartment in turn, noting any smoke contained therein. If the odour of the smoke is present (it is quite pungent) careful examination will reveal its source.

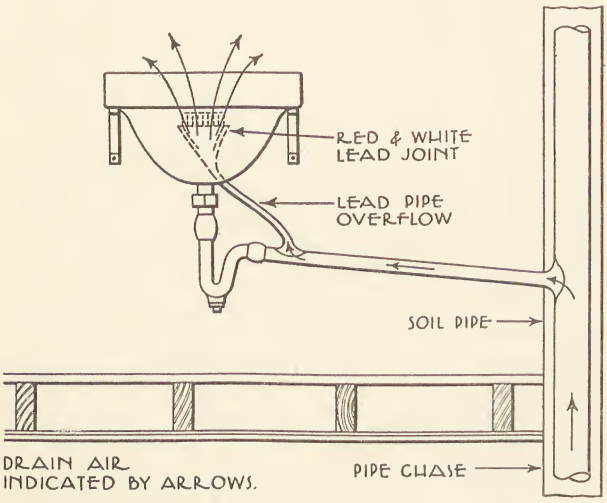


Fig. 5.—A SERIOUS FAULT DUE TO THE OVERFLOW PIPE OF A WASHHAND BASIN BEING CONNECTED TO THE WASTE PIPE AND NOT TO THE INLET SIDE OF THE TRAP

Where Defects Are Found

In the case of light iron soil pipes fixed externally, defects are often found at the back of them, for being fixed flat against the wall, the backs of the pipes are never painted when the house is redecorated, therefore oxidisation of the iron due to moisture is continuous, finally forming an aperture. It should be realised that paint is not only a decorative, but also a protective, agent.

In addition, defects in old soil pipes may be found at the joints, which were originally made of putty or red and white lead; while either the constant expansion and contraction of the pipes, which are held firmly at the sockets, has worked the jointing material out of its position, or oxidisation (rusting) has taken place between the socket and the spigot, finally fracturing the sockets. (Rust occupies a considerably larger space than the iron from which it arises.)

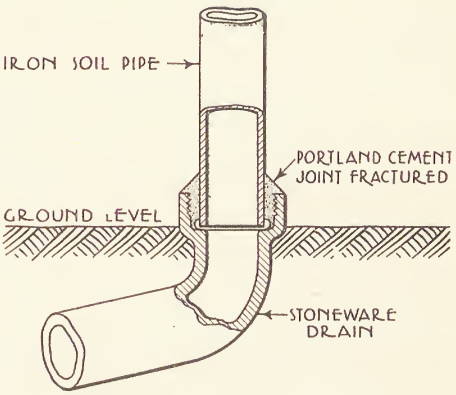


Fig. 6.—THE CONNECTION OF THE SOIL PIPE TO THE STONEWARE DRAIN IS OFTEN FOUND TO BE DEFECTIVE

The soil pipe branch may be of lead, and the pipe opened to receive the closet outlet (Fig. 2), putty forming the joint; either the putty has deteriorated or the lead has expanded at the joint after the putty has hardened. A similar condition may exist at the other end of the branch where it joins the soil pipe, the lead simply being tucked into the junction socket, with putty forming the joint, which is usually found defective (Fig. 3).

The writer recalls a lead soil pipe which was not ventilated, and the lead branch taking the closet discharge was eaten through by gases retained in the branch, possibly aided by impure lead (Fig. 4). In another case, as the result of diphtheria, a smoke test revealed that a lavatory basin situated in the patient's bedroom had its overflow connected to the waste pipe and not to the inlet side of the trap as was required when overflows to lavatory basins were detached. The waste pipe in turn was connected to the lead soil pipe, which in consequence allowed the drain air to pass into the bedroom continuously (Fig. 5).

(Note.—With the modern type of lavatory basin, the overflow takes the form of a secret channel, and forms part of the basin.)

The connection of the soil pipe to the stoneware drain is often found to be defective, particularly when the stoneware socket is showing above ground (as in Fig. 6), where it may easily be fractured accidentally. It may also be due to expansion of the iron soil pipe, or expansion of the Portland cement joint, if made with "hot" cement, i.e. cement not sufficiently air slaked.

Should the tested soil pipe be wholly of lead, especially if exposed to the sun's rays, defects are frequently found due to the varying temperature to which it is subjected. By the constant expansion and contraction, the molecules of lead are parted at the weakest parts of the soil pipe, which finally results in complete fracture. This fracture may often be

seen close to soldered joints and also in the throat of bends where a lead pipe passes in the form of an offset over a projection on the face of a building (Fig. 7).

Chemical Test for Soil Pipe

The soil pipe is sometimes tested with chemicals in conjunction with the drain test, and is stopped off when the odour is emitted from the head of the soil pipe, care being taken to close the apartments, as described for the smoke test.

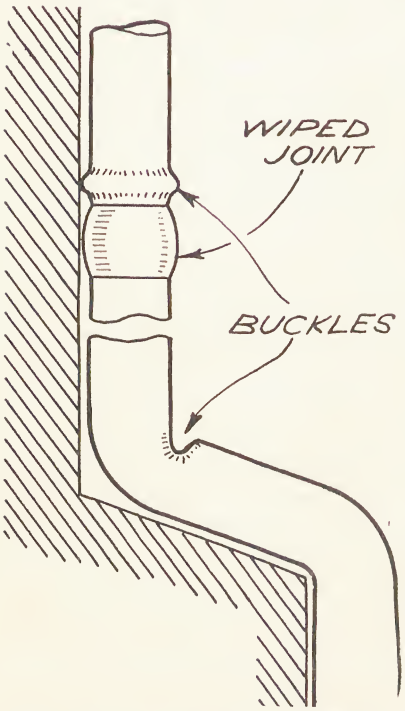


Fig. 7.—BUCKLES ARE SOMETIMES FOUND IN LEAD PIPES AND THESE OFTEN FRACTURE, ALLOWING FOUL MATTER TO ESCAPE

Positive results are frequently obtained on defective light iron soil pipes and their connections, which discharge into the drain via a junction, and are not connected to a manhole. The present marketed form of chemical test was described in the drain-testing section. The method previously adopted was to use oil of cloves or peppermint in hot water, and to pass the fluid into the top of the soil pipe and stopper off.

Waste Pipes from Washing Fitments

If considered desirable to test the vertical waste pipes and branches which take the discharge from washing fitments such as baths, lavatory basins, sinks, and bidets, this can be carried out by means of the smoke test. The test can be applied to the lower end of the waste pipe where it discharges over or into the gully trap.

In some cases, particularly in old buildings, long branch waste pipes exist. Although they do not receive discharges of excremental filth, odours arising from decomposing fat (fat being the basis of soap) may pass into habitable apartments, through defects in the pipes or connections, and are not conducive to good health. It is, therefore, desirable to carry out a test on the waste pipes.

HEATING AND VENTILATION

PART III.—CIRCULATING PUMPS AND ACCELERATORS; SIZES OF PIPES FOR HEATING SYSTEMS

THE essential difference between an accelerator and a pump as used in heating circuits is that an accelerator has a by-pass which permits the circulation of the water to continue by gravity when the machine is stopped either deliberately or accidentally.

Both pumps and accelerators are commonly of the centrifugal type and are usually driven by an electric motor. Gas and oil engines are sometimes used in remote districts where electricity is not available. Where steam is obtainable at sufficient pressure, the steam turbine may be usefully employed as a prime mover and the exhaust steam from it utilised for heating the water in the system by passing the steam through a calorifier.

Where the frictional resistance in the pipe circuit is so high that no circulation can be obtained other than by mechanical means, the provision of a by-pass is useless, and in order to safeguard the system, it is advisable to provide duplicate pumps. In the event of the failure of one, the other can then be started up.

If there is no stand-by pump, there is a possibility, in the event of a breakdown, of the temperature of the water in the boiler rising to above steaming-point. The importance, in any case, of fitting a safety valve or open expansion pipe of adequate area to the boiler cannot be too strongly emphasised.

The centrifugal pump consists essentially of an impeller mounted on a driving shaft and surrounded with a casing designed to carry the water from the inlet to the impeller, and from the impeller to the discharge branch. The arrangement of the water-ways and their size in relation to the duty of the pump have an important effect upon the efficiency percentage.

The impeller is usually of gun-metal and the casing of cast iron. The driving shaft is supported by watertight bearings, and projects through them on one side of the pump. The shaft extension is fitted with either a pulley or half-coupling according to whether it is to be driven by a belt or directly from a motor or turbine.

It is not possible, commercially, to design a pump to work with a maximum efficiency under all the actual combinations of frictional resistance and gallons delivered which arise in practice. The percentage

of efficiency, therefore, varies considerably and the best results depend upon how nearly the client's requirements coincide with the manufacturer's most efficient rating.

For small pumps an over-all efficiency of 30 per cent. may be considered good for an electrically driven unit, and for arriving at the electrical consumption the formula $\frac{10 \times G \times H \times 100 \times \cdot 746}{33{,}000 \times E}$ will give kilowatts.

G = Gallons per minute.
H = Head in feet.
E = Percentage of over-all efficiency of pump and motor.

Simplifying the formula we have :

$$\frac{\cdot 0226 \times G \times H}{E}$$

The accelerator by-pass is usually fitted with an automatic valve, which is kept closed, when the machine is running, by the difference in pressure on the inlet and delivery sides. This pressure difference ceases when the accelerator is stopped, and the valve swings open.

In the direct-driven accelerator or pump, the motor shaft is brought into alignment with the accelerator spindle and the two machines are coupled together to form one unit. Where the accelerator is fitted with a rope or belt drive, the motor is sometimes bolted to the top of the casting in order to effect a saving in floor space. Such an arrangement is adopted by the makers of the " Super-Selfix."

It will be noted that this model incorporates isolating valves between the pump and by-pass which enable the pump to be detached for overhaul or repairs without interfering with the working of the installation.

The engineer should be careful to ascertain particulars of the electric supply in all cases where an electrically driven accelerator is required. If direct current is available it is necessary to know only the voltage, but if alternating current is laid on particulars should be obtained of the voltage, phase and periodicity. For small units single-phase motors are satisfactory, but for larger machines a 3-phase supply should be brought in.

Regard should also be given to the conditions under which the motor is to operate. Damp or badly ventilated boiler houses and situations where dust or fumes are likely to impair the motor windings should be given consideration. If the manufacturers are advised, they will recommend and submit proposals for suitably protected equipment.

The most satisfactory position for the accelerator in the pipe circuit is in the return pipe, fairly close to the boiler. In this position the temperature of the water is relatively low and the boiler attendant is at hand for ready supervision.

Precautions are necessary at times to prevent the transmission of

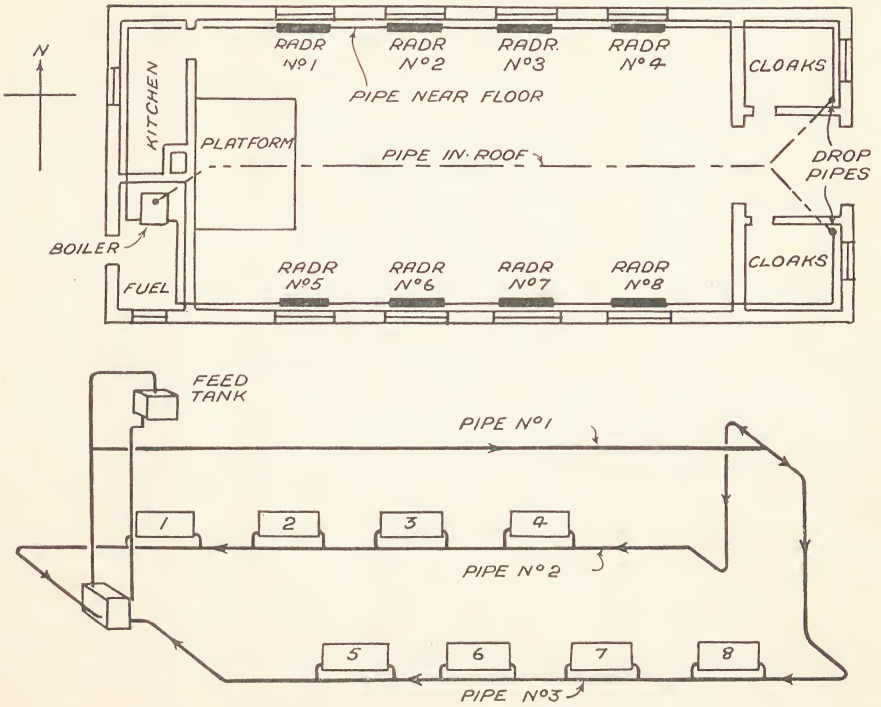


Fig. 1.—TYPICAL SINGLE-PIPE HEATING SYSTEM FOR A RECREATION ROOM OR SMALL ENTERTAINMENT HALL, USING PIPES AND RADIATORS SERVED BY A BOILER 18 IN. BELOW FLOOR LEVEL

noise from the accelerator. In such instances it is advisable to introduce an anti-vibration base of cork or similar material under the machine, and the motor manufacturers should be informed of the necessity for silence in operation.

Sizes of Pipes for Heating Systems

The effect produced by an accelerator or pump in the circulating system is an increase in the circulating head, which, instead of being measured in inches or fractions of an inch can be stated in terms of feet. The carrying capacities of the pipes are thereby increased considerably, with the result that it is possible to use pipes of comparatively small diameters for large and extensive installations where circulation by gravity would be impracticable.

If we consider the comparative carrying capacities of a 2-in. diam. pipe circuit having a natural circulating head of 0·4 in. per 100 ft., and the same circuit fitted with an accelerator giving a head of 1 ft. per 100 ft., the corresponding flow of water will be :—

By gravity circulation, 1,820 lb. per hour.
By accelerated circulation, 9,150 lb. per hour.

A simple and reliable formula evolved by Thomas Box is one used extensively for determining the sizes of pipes for accelerated systems. This gives :—

$$H = \frac{G^2 \times L}{(3d)^5}$$

Where H = Head in feet.
G = Gal. per minute.
L = Length of pipe in yards.
d = Diameter of pipe in inches.

From this formula the charts on page 110 have been prepared, giving the flow of water in pounds per hour and the corresponding resistance in feet per 100-ft. run of pipe.

It is usual to allow an average resistance of from 1 to 2 ft. per 100-ft. run in accelerated systems, and on this basis the total head is determined against which the pump will be required to work. Assume, for example, that the length of the longest circuit is 1,500 ft., then, by allowing 1½ ft. per 100 ft., the total head will be :—

$$1\tfrac{1}{2} \times 1{,}500 \div 100 = 22\tfrac{1}{2} \text{ ft.}$$

Gravity and Forced Circuits

The principles upon which the sizes of pipes are determined can now be applied in considering various heating layouts. The following examples are of common occurrence in general practice and will serve to illustrate some of the methods employed.

Example 1.—It is proposed to heat a recreation room or small entertainment hall, by pipes and radiators served by a boiler fixed 18 in. below floor level. The temperature inside the room is to be maintained at 60° F. and circulation must be by gravity. The level of the boiler relative to the floor level limits the choice of a system to one in which the circuit height must be some distance above floor level in order to obtain a satisfactory circulation. A single-pipe system is therefore decided upon as shown in the plan and diagram (Fig 1).

Assuming that the calculated heat losses are 40,000 B.T.U. per hour, then from a rough approximation it is considered that a 2-in. diameter flow pipe will be required. Taking the mean temperature difference of the pipe in the roof space to be 175° — 45° = 130° F., the length 60-ft., and the efficiency of the insulating covering 60 per cent., then the heat loss will be :—

$$\frac{40}{100} \times 60 \times 183 = 4{,}400 \text{ B.T.U. per hour.}$$

The factor 183 is the transmission in B.T.U. per hour per foot run of 2-in. pipe at 130° temperature difference.

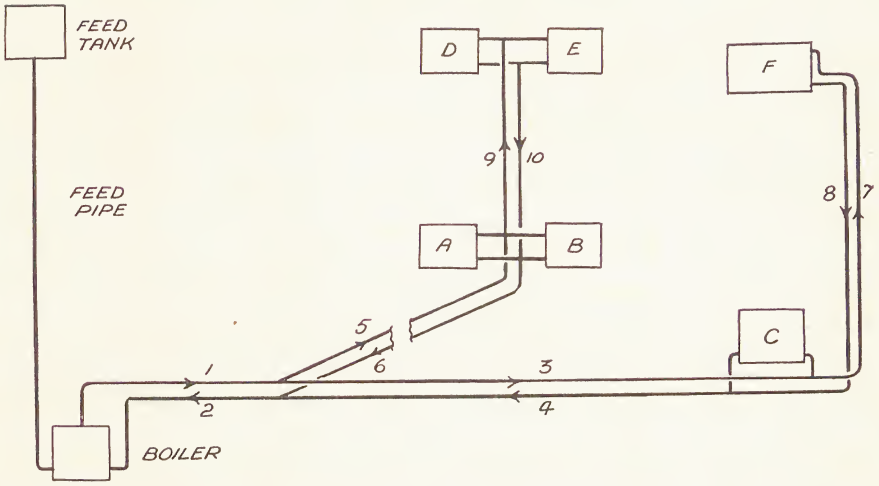


Fig. 2.—AN ARRANGEMENT OF A TYPICAL TWO-PIPE UP-FEED SYSTEM FOR A PRIVATE HOUSE INSTALLATION

Taking the height of the pipe above the boiler to be 15 ft., we can proceed to calculate the mean circuit heights and circulating heads.

Let the total transmission from pipe No. 2 = 21,000 B.T.U. and that from pipe No. 3 = 19,000 B.T.U.

Then the mean height of the circuit formed by pipes 1 and 2 will be :—

$$(1) \qquad \frac{(4{,}400 \times 15) + (21{,}000 \times 0)}{4{,}400 + 21{,}000} = \frac{66{,}000}{25{,}400} = 2{\cdot}6 \text{ ft.}$$

Similarly for pipes 1 and 3.

$$(2) \qquad \frac{(4{,}400 \times 15) + (19{,}000 \times 0)}{4{,}400 + 19{,}000} = \frac{66{,}000}{23{,}400} = 2{\cdot}83 \text{ ft.}$$

The corresponding circulating heads for a flow temperature of 180° F. and return 140° F. are found by multiplying by ·152 :—

(1) $2{\cdot}6 \times {\cdot}152 = {\cdot}395$ in.
(2) $2{\cdot}83 \times {\cdot}152 = {\cdot}43$ in.

It is convenient now to tabulate the data as follows :—

Pipe No.	*Radiation B.T.U.*	*Load B.T.U.*	*Length Ft.*	*Diam. In.*	*Resistance for 40° Drop. In.*
1	4,400	44,400	86	2	·146
2	21,000	23,300	120	1½	·24
3	19,000	21,100	100	1½	·17

The loads on pipes 2 and 3 are obtained by proportioning the total load according to their radiation, thus :—

$$\text{Pipe No. 2.} \qquad 44{,}400 \times \frac{21{,}000}{40{,}000} = 23{,}300 \text{ B.T.U.}$$

$$\text{Pipe No. 3.} \qquad 44{,}400 \times \frac{19{,}000}{40{,}000} = 21{,}100 \text{ B.T.U.}$$

On comparing the circulating head by the resistance of the piping, we have :—

(1) Circulating head = ·395 in. Resistance ·386 in.
(2) ,, ,, = ·43 in. ,, ·316 in.

As the difference in circulating head and resistance of the piping is greater in circuit (2) than in (1) it would be advisable to fit a lockshield regulating valve in pipe No. 3 in order to equalise the circuits.

The temperatures of the radiators on single-pipe circuits are usually taken at approximately 10° less than the temperature of the pipe, and the pipe temperature can easily be determined as follows :—

The difference in the temperatures of the flow and return pipes at the boiler, viz. 40°, is due to the loss by radiation of 44,400 B.T.U. The temperature drop, therefore, along any particular pipe can be found by multiplying the total drop by the radiation and dividing by the load. The drop, for instance, in pipe No. 1 in the above example, will be :—

$40° \times 4{,}400 \div 44{,}400 =$ approx. 4° ; that along pipe No. 2, $40° \times 21{,}000 \div 23{,}300 = 36°$; similarly for pipe No. 3, $40° \times 19{,}000 \div 21{,}100 = 36°$.

The mean temperatures of the radiators will be :—

$$140° + \frac{36}{2} - 10° = 148° \text{ F.}$$

Pipe Nos.	*Net Load B.T.U.*	*Load Including 30% Margin for Mains Losses*	*Length Ft.*	*Available Head In./100 Ft.*	*Diam. of Pipe In.*	*Resistance In.*
1 & 2	36,000	46,800	30	—	1½	·225
3 & 4	10,000	13,000	30	*To radr.* C 1·52	1	·153
5 & 6	26,000	33,800	40	*To radrs.* A & B 1·3	1¼	·41
7 & 8	4,000	5,200	38	*To radr.* F 2·33	½	1·14
9 & 10	10,000	13,000	27	*To radrs.* D & E 2·35	¾	·6

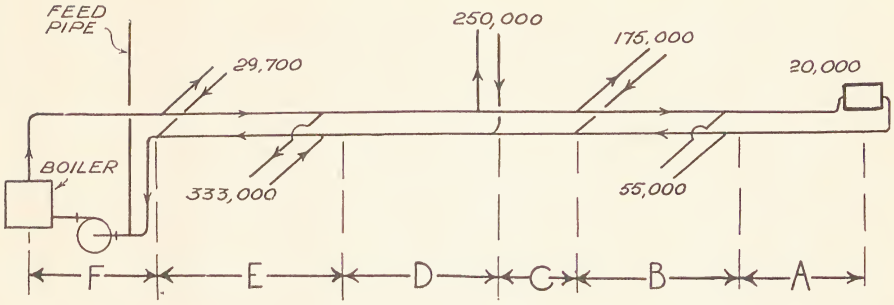


Fig. 3.—THE ACCELERATED SYSTEM

In which the pipes in the main trunk line are sized so that the total resistance approximates to the pump head.

Example 2.—The diagram Fig. 2 shows the arrangement of a typical two-pipe up-feed system for, say, a private house installation.

In this case the boiler is situated in a basement. The height from the centre of the boiler to the ground-floor radiators, A, B and C, is 6 ft., and to the first-floor radiators, 15-ft. The corresponding circulating heads are, for a flow temperature of 180° F. and return 140° F. :—

$$6 \times \cdot 152 = \cdot 912 \text{ in. and } 15 \times \cdot 152 = 2 \cdot 28 \text{ in.}$$

By compiling the table on page 108, the sizes of the various pipes are easily determined.

Circulating head for radiator C	= ·912 in.
Total resistance in pipes 1, 2, 3, 4	= ·378 in.
Circulating head for radiators A and B	= ·912 in.
Total resistance in pipes 1, 2, 5, 6	= ·635 in.
Circulating head for radiators D and E	= 2·28 in.
Total resistance in pipes 1, 2, 5, 6, 9, 10	= 1·235 in.
Circulating head for radiator F	= 2·28 in.
Total resistance in pipes 1, 2, 3, 4, 7, 8	= 1·518 in.

Example 3.—In the accelerated system shown in the diagram Fig. 3, the pipes in the main trunk line are sized so that the total resistance approximates the pump head. If the sizing is done methodically, the total head and the head available at various points in the system can be easily ascertained. The branch circuits can then be sized according to the head available at the junction to the main pipe line.

Let the total length equal 1,000 ft. and the temperature difference at the boiler 30° F. Then allowing an average resistance of 1 ft. per 100-ft. run, we can size the pipes as in the table, from which we find that the total resistance is 10 ft. which is the head against which the pump must operate.

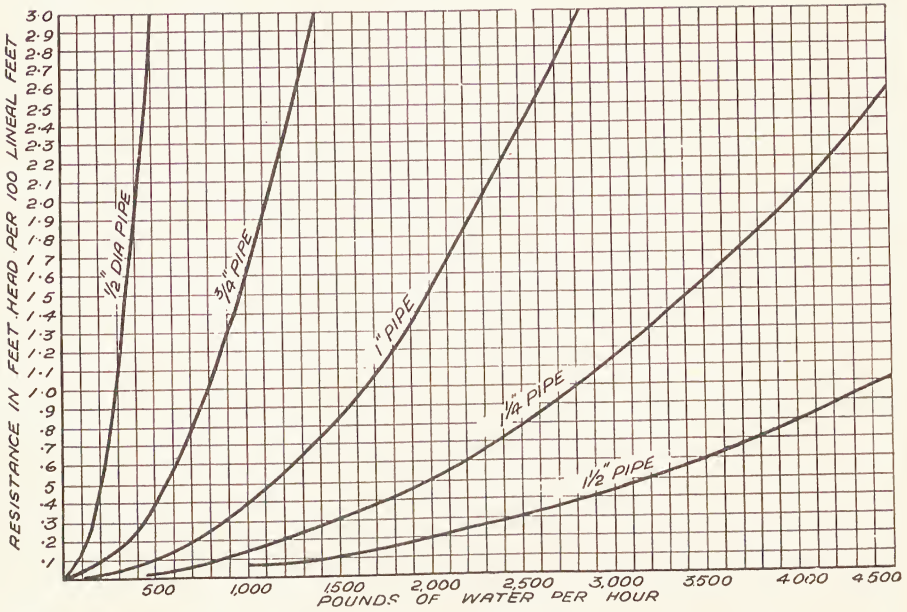


Fig. 4.—CHART SHOWING FLOW OF WATER FOR ACCELERATED SYSTEMS

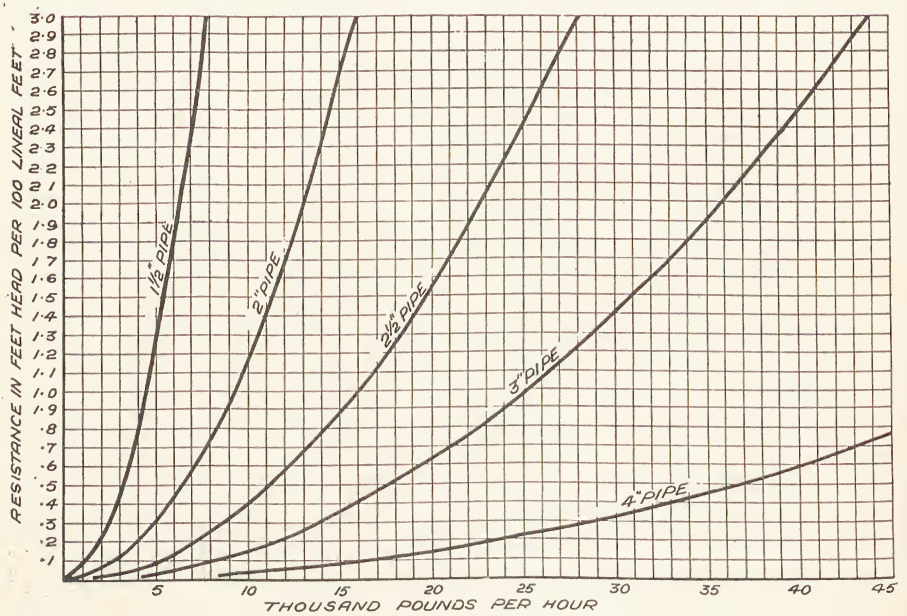


Fig. 5.—CHART SHOWING FLOW OF WATER FOR ACCELERATED SYSTEMS

Section	*Load * B.T.U./Hr.*	*Length Ft.*	*Diam. In.*	*Resistance Ft.*	*Head Available at Junction*
A	24,000	150	¾	·87	·87
B	90,000	180	1¼	2·07	·87 + 2·07 = 2·94
C	300,000	80	2	·94	2·94 + ·94 = 3·88
D	600,000	200	3	1·26	3·88 + 1·26 = 5·14
E	1,000,000	240	3	3·73	5·14 + 3·73 = 8·87
F	1,350,000	150	4	1·13	—
				Total Resistance	10·00

* 20% added to net load for mains losses.

In the space available it is not possible to explore all the methods by which the sizes of pipes can be determined. The accurate sizing of pipes, moreover, is one which requires considerable attention on the part of the engineer, and the reader is referred to the works of such authorities as Reitchel and Weisbach for more comprehensive treatment of the subject.

Feed and Expansion Tanks

These are usually of galvanised mild steel and their capacity should be sufficient to hold the increase in the volume of water by expansion when heated. The water content of the system should be calculated and as the expansion will increase the bulk by about $\frac{1}{23}$ the tank capacity should be equal to this amount, plus an allowance for the cold-water level maintained by the ball valve, and the reduction in the total capacity by the position of the overflow pipe. It is usual to add 50 per cent. for these allowances. The water contents of boilers and radiators are given in the makers' catalogues, and reference should be made to the table given on page 37 for the water capacities of pipes.

The tank should be fixed well above the highest point of the system, and if a water supply is laid on, the buoy valve should be adjusted so that the cold-water level is kept as low as possible.

The overflow pipe should not be less than 1¼-in. diameter, and should be arranged to discharge outside the building, where, in the case of failure of the buoy valve, any excessive overflow will be easily noticeable.

The feed pipe may be connected to any part of the system where there is no possibility of it being isolated from the boiler by the inadvertent closing of valves. In accelerated systems it is usual to connect it close to the inlet side of the accelerator or pump. It should not be less than ¾-in. diameter, and for installations where the boiler is rated above 500,000 B.T.U. a 1-in. diameter pipe is recommended.

QUESTIONS AND ANSWERS

What is the essential difference between an accelerator and a pump used in heating circuits ?

An accelerator has a by-pass which permits the circulation of the water to continue by gravity when the machine is stopped either deliberately or accidentally.

What formula would you use to arrive at the electrical consumption in kilowatts of an electrically-driven unit for a pump ?

$$\frac{10 \times G \times H \times 100 \times \cdot 746}{33{,}000 \times E}$$

Where G = gallons per minute
H = head in feet
E = Percentage of over-all efficiency of pump and motor.

The formula can be simplified to $\frac{\cdot 0226 \times G \times H}{E}$

What is the most satisfactory position for the accelerator in a pipe circuit ?

The accelerator should be placed in the return pipe, fairly close to the boiler.

What precautions can be taken to prevent noise from the accelerator ?

It is advisable to introduce an anti-vibration base of cork or similar material under the machine.

What is the effect produced by an accelerator or pump in the circulating system ?

It gives an increase in the circulating head which instead of being measured in inches or fractions of an inch can be stated in feet.

What is the result of this ?

It is possible to use pipes of comparatively small diameters for large and extensive installations where circulation by gravity would be impracticable.

What simple and reliable formula would you use for determining the sizes of pipes for accelerated systems ?

$$H = \frac{G^2 \times L}{(3d)^5}$$

Where H = Head in feet.
G = Gallons per minute.
L = Length of pipe in yards.
d = diameter of pipe in inches.

SANITARY SCIENCE APPLIED TO BUILDING

PART II.—METHODS OF PREVENTING DAMPNESS

IN a previous section (pages 65–80) we have dealt with the cause and prevention of dampness arising from the ground and soaking downwards through walls. There are other items which need attention in the construction of a building to prevent the penetration of dampness, such as that caused by rain beating against the faces of exposed walls ; rain-water pipes and eaves gutters improperly fixed and of insufficient capacity to deal with the volume of water they are called upon to carry during heavy rain ; improperly formed window cills, and various items of roofing work.

In addition to the foregoing, dampness is also caused by defective pipes and fittings, but these defects usually occur some time after premises have been built, and at the present the aim is to attain an ideal in construction to prevent dampness arising, and not to inquire into the cause of dampness in old buildings, as this is being dealt with in another section. At the same time, attention must be given to the general arrangements of pipes and fittings, to prevent possible damage and subsequent leakage.

Walls and Driving Rain

Walls exposed to the action of driving rain often suffer considerably from dampness, and in the majority of cases it is due to the quality of the materials used and the mode of construction. A wall composed of inferior bricks of a porous and absorptive character will permit dampness to penetrate, whether it is built in an exposed position or not, whereas a wall built of good, sound brickwork will resist the passage of moisture even during prolonged rain. Walls constructed of good-quality building stone or concrete will resist the penetration of moisture and can be said to be impervious.

After a heavy, driving rain, the moisture from a stone, concrete, or good brick wall should evaporate fairly quickly, but with materials of an absorptive character the rate of evaporation is very slow, owing to the depth to which the moisture penetrates, and which results in the wall becoming waterbound during wet weather, thus giving rise to dampness on the inner face of the wall. Even though the dampness may not penetrate the wall completely, the moisture held in the material is not conducive to a healthy building.

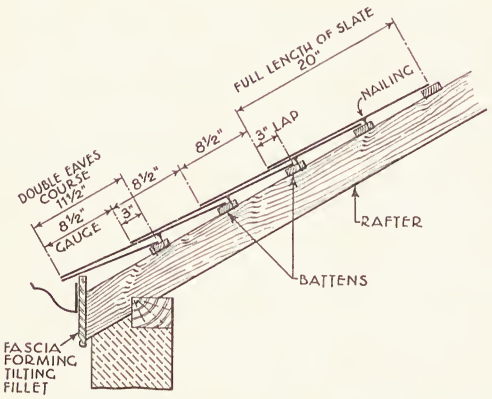


Fig. 1.—SECTION SHOWING MARGIN, LAP, AND DOUBLE EAVES COURSE ARRANGED FOR 20-IN. BY 10-IN. SLATING CENTRE-NAILED TO BATTENS

Protection

In very exposed positions, where a wall is likely to suffer from the effects of driving rain, precautions should be taken to prevent the building becoming damp from this cause. It is the best plan to provide protection at the outset, rather than risk a damp wall, and the subsequent recourse to various methods of surface treatment to effect a cure without structural alterations.

Various methods of protection are available to suit different classes of property, and the question of appearance is perhaps the chief factor in deciding on any particular treatment in order not to upset the design of a building, and the following are suggested: a cavity wall with a well-ventilated air-space between an outer skin and the inner wall; a vertical damp-proof course constructed within the wall; facings of glazed bricks or similar materials; cement rendering; rough cast; tile hanging or slate hanging; asbestos-cement sheeting fixed in panels. Cement rendering or rough cast should be made safer by the admixture of a good waterproofing medium to the mix.

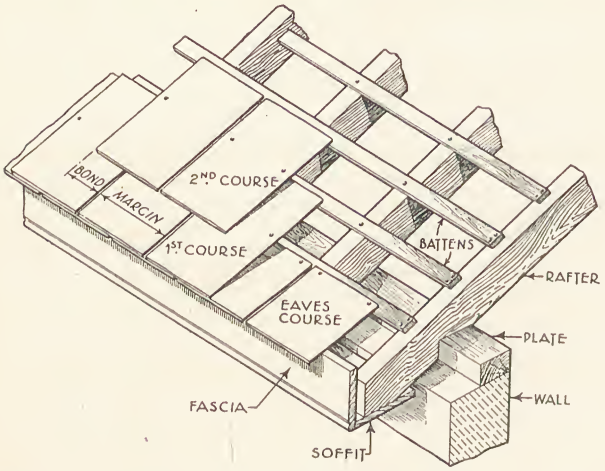


Fig. 2.—SHOWING ARRANGEMENT OF DOUBLE EAVES COURSE TO OVERHANGING ROOF WITH BATTENS ONLY

ROOFING

A sound, weather-proof roof is an essential feature of every building, irrespective of its class or of the type of covering it is proposed to adopt. The construction should be such that the interior of the roof is warm in winter and cool in summer.

One has the choice of a variety of materials, in order to suit the architectural features of a building of any type or to meet other special requirements, and a brief outline is given here of different types of roofing materials suitable for domestic or industrial premises.

Asphalte

Durable and tough, sanitary, non-absorbent, frostproof, non-inflammable, dries quickly after rain. It is easily applied, is jointless, and being slightly elastic will yield to slight settlement. Usually applied in two layers, and can be laid on concrete or boarding.

Slates

Obtainable in various sizes and colours; form a neat, smooth covering as they lie closely together. Lighter than tiles. When of good quality are non-absorbent. They are durable; bad conductors of heat; liable to strip during high winds, but are easily repaired.

Fixing

They are fixed to close boarding or battens, and can be either head nailed or centre nailed (Fig. 3). The latter is a protection against stripping in high winds.

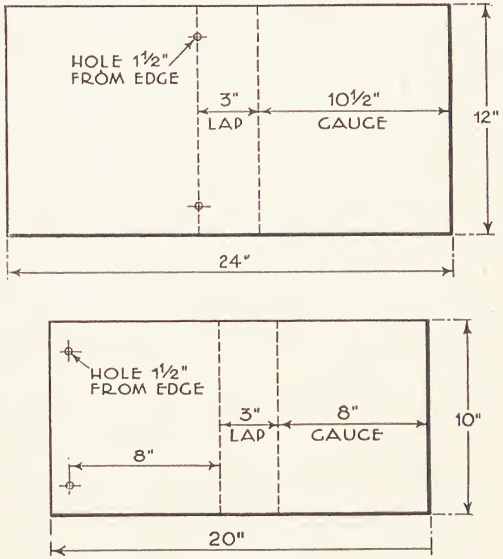


Fig. 3.—TOP, DUCHESS SLATE HOLED FOR CENTRE NAILING. BOTTOM, COUNTESS SLATE HOLED FOR HEAD NAILING

Double Eaves Course

This is the first course of slates, laid at the lower portion or "eaves" of a roof (Figs. 1 and 2). An eaves course also occurs where there is a break or projection, such as a chimney or skylight. The marginal portion of the slates is trimmed off to form the eaves course. The practice of laying slates lengthwise to form this course is not to be recommended.

Reason for Eaves Course

Where a vertical section is taken through the width of slating, two thicknesses of slate should be seen, and at each lap, three thicknesses. See Fig. 1.

Ridge Course

This is the course introduced at the "ridge," for a similar reason as the "eaves" course.

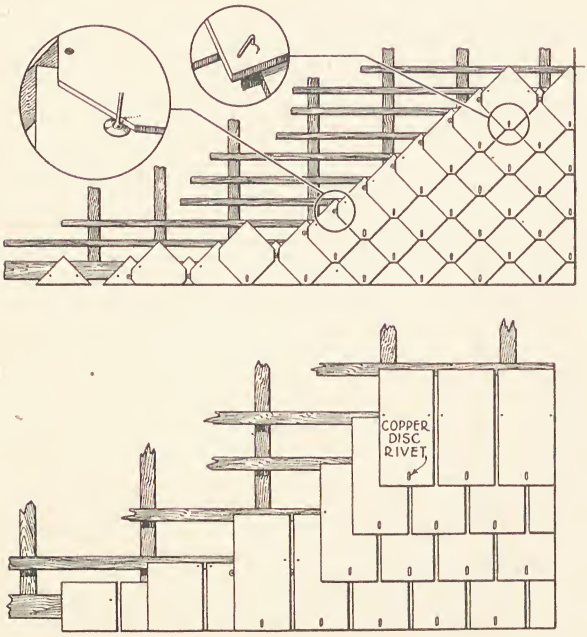


Fig. 4.—"POILITE" ASBESTOS CEMENT SLATING
Top, honeycomb pattern; bottom, rectangular pattern. (*Turner's Asbestos Cement Co.*)

Dressing

Before slating is commenced the slates are dressed and holed. Where valleys, hips, etc., occur, the slates are usually dressed to a template.

Nails for Fixing

These may be of copper, zinc, composition, or iron. The last named are very liable to rust unless effectually galvanised. For good-class work, copper or composition nails are recommended. Two nails are used for each slate, and the holes for them should be made $1\frac{1}{2}$ in. from the sides of the slate (Fig. 3).

Asbestos "Poilite" Slates

An economical and artistic roof covering. Obtainable in various colours. Light in weight, requiring less roof timbers. Impervious to the elements. Maintenance costs practically nil. Useful in industrial areas where the atmosphere is of an acid character.

Fixing

They are fixed to boarding or battens. Each slate is secured by two $1\frac{1}{4}$-in. galvanised nails of 11 B.W.G., and also a copper disk rivet, to ensure rigidity and prevent dislodgment during high winds. Copper nails are recommended for use in districts where the atmosphere is of an acid character (Fig. 4).

"Poilite" Pan Tiles

Also an artistic roof covering, light in weight, economical in roof sub-structure; fireproof, easily fixed, and form an effective insulator against heat and cold. Compared with clay pan tiles they effect a considerable reduction in building costs for the supporting structure.

Fixing

The tiles should be fixed to 2-in. by 1-in. battens, spaced at $11\frac{3}{4}$-in. centres, with two galvanised nails per tile, one $1\frac{1}{2}$ in. and one 2 in. When on open battens, the pitch of roof should not be less than 40 degrees. When boarding and/or felt is used under the tiles, a pitch of 30 degrees can be adopted.

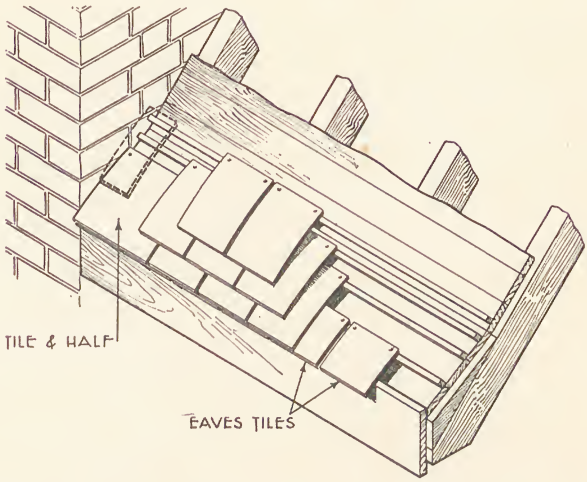


Fig. 5.—TILING, SHOWING EAVES COURSE AND USE OF TILE AND HALF

Note.—The next course but one above the tile and half will require a half-tile as indicated by dotted lines.

Asbestos-cement Tiles and Sheets

A very suitable roof covering for industrial buildings, garages, etc. The "Trafford" tiles are formed with four corrugations, with three flats between them. "Everite" corrugated sheets are formed with $10\frac{1}{2}$ corrugations per width of sheet. Various accessories are obtainable, such as apron pieces, ridgings, louvre blades, open and dead lights, etc. Like other asbestos-cement roofing, is fireproof and economical in sub-structure.

Clay Tiles

Very neat and pleasing in appearance, and being obtainable in many colours, shapes, and sizes are suited to many styles of architecture. They are non-conductors of heat; rather heavy, and require strong supports. Best suited to roofs of high pitch (Fig. 5).

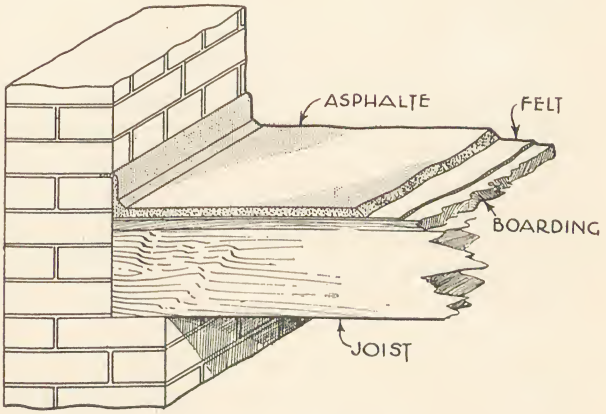


Fig. 6.—FINISH OF UPTURNED ASPHALTE TO FLAT ROOF

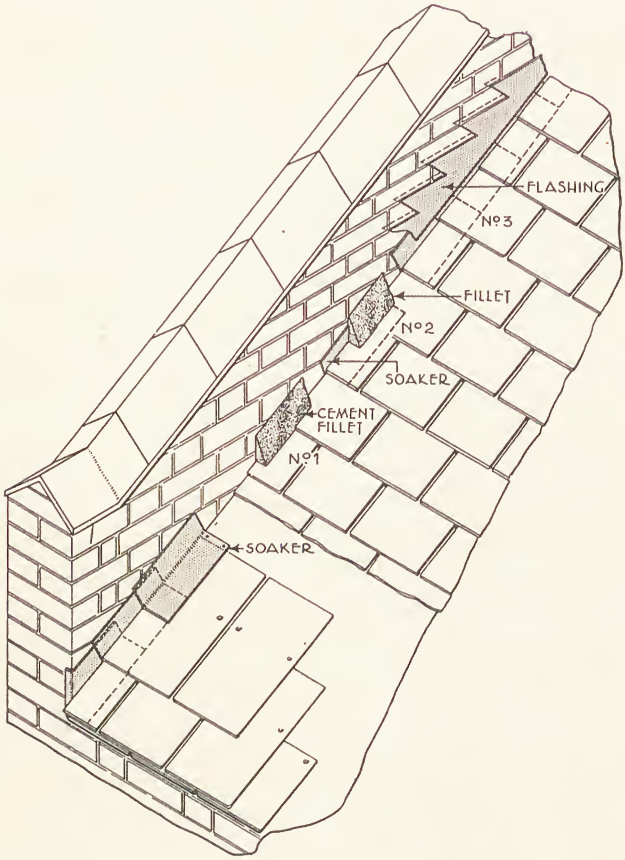


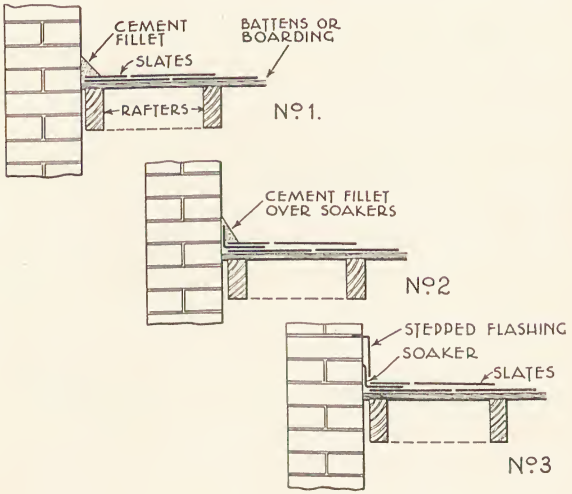
Fig. 7.—FINISH OF SLATING TO PARTY WALL, SHOWING HOW SOAKERS ARE LAID AND FIXED, AND THREE METHODS EMPLOYED TO MAKE GOOD THE JUNCTION

No. 1.—Cement fillet only—cheap and incorrect.

No. 2.—Cement fillet with soakers—an improvement on No. 1.

No. 3.—Soakers and stepped flashing—the correct method.

On the right are shown sections through these three methods.



Fixing

Tiles may be obtained plain, without camber or nibs, but holed for two nails or pegs, and also with camber, projecting nibs, and holed, and, when required, of an ornamental type. The nibs on the upper edge are for suspending the tiles from the battens, and two nails or pegs should be used in addition. In order to obtain the proper bond and to save cutting, special tiles are made, known as "half-tile," "tile and a half," "eaves," and "double ridge" tiles.

Thatch

When properly laid is impervious to

moisture and possesses good weathering qualities. Is a good non-conductor of heat and is small in cost. Great danger from fire, is insanitary, harbours dust and vermin, etc. Difficulty in fixing eaves gutters and making good to walls. Liable to strip during high winds.

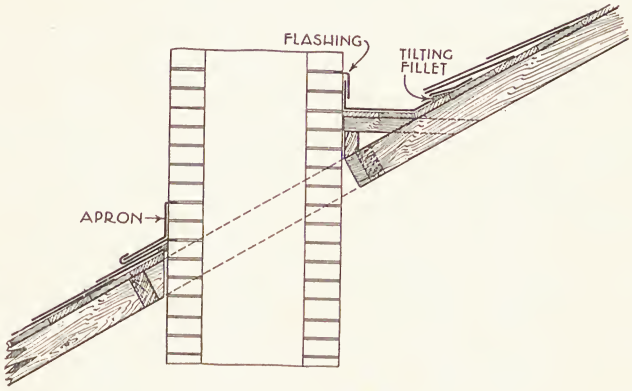


Fig. 8A.—JUNCTION OF ROOF WITH CHIMNEY STACK.
Section showing gutter with double eaves course of slates, and apron piece to front.

Fixing

Thatch is laid on laths fixed to rafters, and secured by tying or pegging down. Tarred string is used to secure the thatch to the laths, and the top thatch is secured to the bottom thatch by pegs which are thrust through.

Cement

A non-absorbent covering suitable for flat roofs. Sanitary; dries out quickly after rain; fire-resisting. Liable to crack owing to expansion and contraction. Not recommended for use by itself. Usually laid in panels.

Lead

A heavy material requiring strong support; very malleable and easily adapted to suit any position. Is suitable for flat or pitched roofs, but for the latter often considered unsuitable owing to weight and liability to creep from position. A useful material to use in conjunction with tiles or slates for gutters, flashings, aprons, etc.

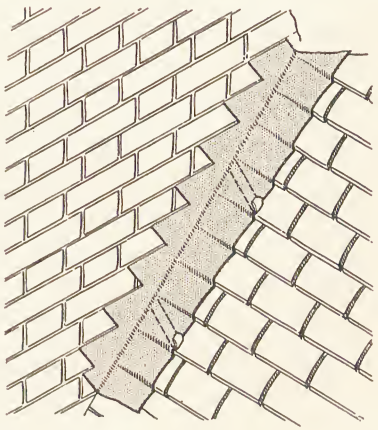


Fig. 8B.—STEP-AND-COVER FLASHING TO TILED ROOF FINISHED AGAINST BRICKWORK

Copper

Very light and durable; fire-resisting; non-rusting; expansion and

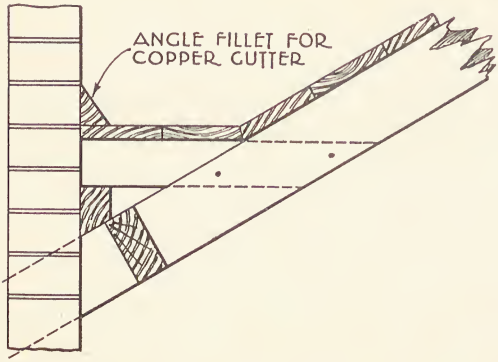


Fig. 9.—SECTION SHOWING CHIMNEY GUTTER PREPARED FOR COPPER

contraction small. A useful material for steep pitches. Weathered copper is pleasing in appearance, due to the "patina" which forms. Like lead, it is useful in conjunction with slates or tiles for forming gutters, flashings, etc.

Zinc

A light material, easily fixed, and more economical in first cost than either lead or copper. Not liable to slip from position. Average life twenty-five to thirty years. Is not fireproof, and is unsuited for acid-laden atmospheres. Is often used in conjunction with slates and tiles for gutters, flashings, etc.

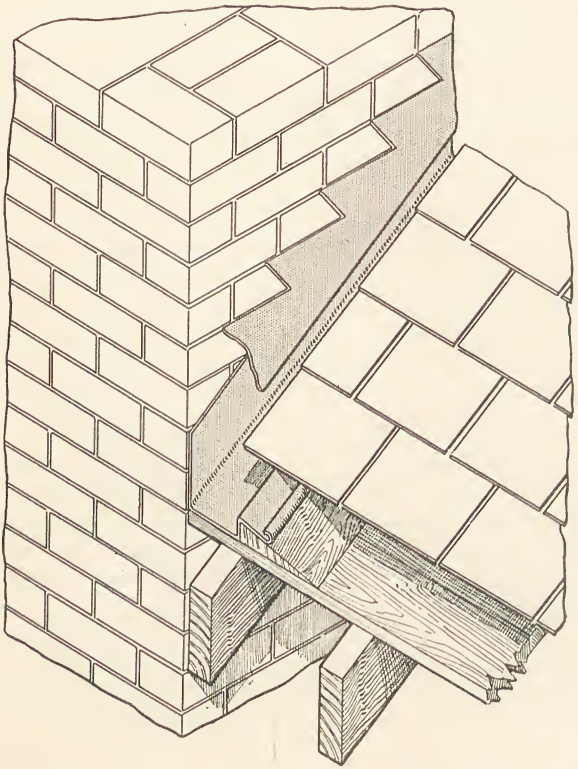


Fig. 10.—APPLICATION OF SECRET GUTTER TO ROOF JUNCTION WITH BRICKWORK

Fixing

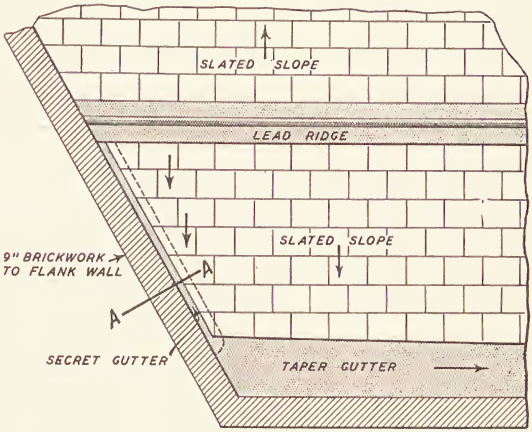
Lead, copper, and zinc are laid in sheets of various sizes, and may be shaped to fit the different forms met with in covering roofs. Joints are formed by laps, welts, drips, rolls, or seams, according to the type of roof and the position in which the joints occur. Lead may be fixed without the use of solder excepting that required for connecting the outlet pipes to roof cesspools and for making the angles to the cesspool. Copper and zinc are also laid by non-solder processes, but

for certain shaped pieces of roofing, soldering or a similar form of jointing must be used to make the seams watertight.

Use of Boarding

The manner in which roofs are prepared for slating or tiling varies with the class of property being erected. The commonest method is simply to nail the battens to the rafters, and then fix the slates or tiles, without further protection.

Another method sometimes practised is to line the under side of the roof with grooved and tongued boarding to keep the roof space free from dust and draughts.



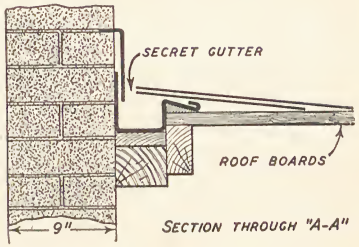


Fig. 11.—PLAN AND SECTION OF SECRET GUTTER

In most good-class work it is the practice to lay close boarding on the rafters, and cover this with sarking felt as slating proceeds. For tiled roofs the battens are fixed over the felt. The use of close boarding and felt renders a roof more efficient not only against the elements, but also with regard to the condition of the roof space, especially during the winter; in the winter months one has only to enter a roof space where battens alone are used, to realise the truth of this statement.

It is well known that in much of the property which has been, and is still being, erected, the storage cistern is placed in the roof space, where it is subject to dust and soot and the action of frost, as it is seldom if ever provided with a

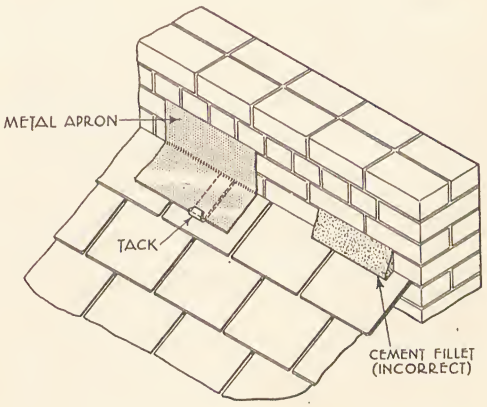


Fig. 12.—FINISH TO WALL AT TOP OF SLATED SLOPE

Showing correct and incorrect methods of making good the junction.

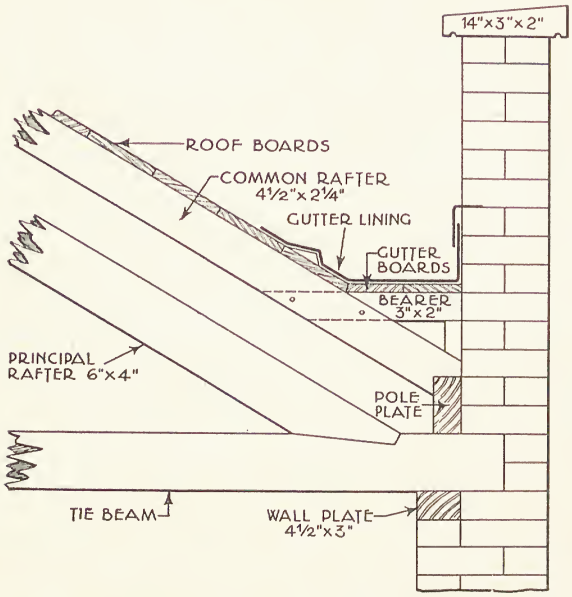


Fig. 13A.—SECTION THROUGH TAPERING PARAPET GUTTER

suitable cover or protection of any sort. The effects of a non-boarded roof in these cases are fairly obvious. Asbestos-cement sheeting is also a suitable material to use in place of boarding.

Roof Junctions

In the majority of roofs, the construction is such that junctions must be formed at various points, such as party walls, parapet walls, chimneys, skylights, dormers, and similar projections, and also where sloping roofs intersect, such as at valleys and hips. These junctions are made water-tight in various ways according to the type of roof covering used. In the case of flat roofs covered with asphalte, the latter is continued up the wall face and finished by turning it into a joint of the brickwork (Fig. 6).

On slated or tiled roofs, sheet zinc, copper, or lead is often used to form the junction, although on many tiled roofs special-shaped valley and angle tiles are now used to form what are usually referred to as tile-

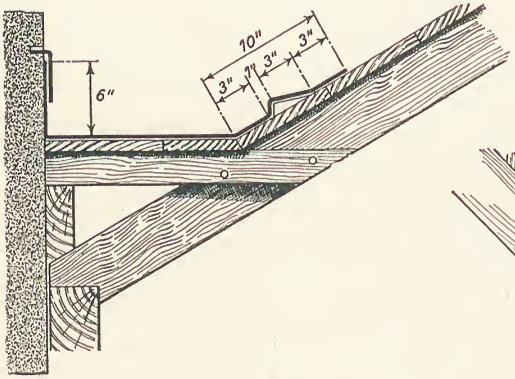
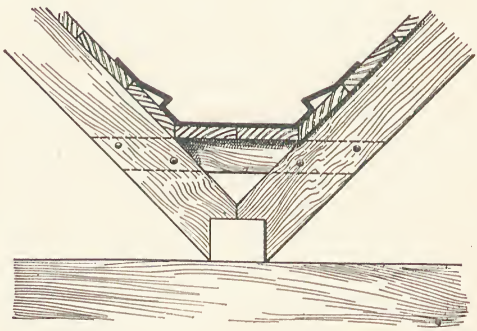


Fig. 13B. — ANOTHER SECTION THROUGH TAPERING PARAPET GUTTER

Fig. 14.—TAPERING GUTTER BETWEEN SLOPING ROOFS



swept valleys. Roofs covered wholly with zinc, copper, or lead are made good at the junctions with flashings or aprons of the same material arranged to suit each variation of the roof.

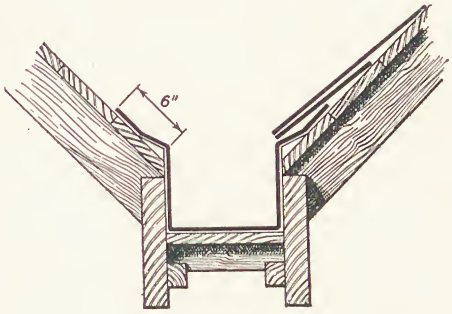


Fig. 15.—SECTION OF BOX GUTTER BETWEEN SLOPING ROOFS

Soakers

These form an important part in making many of the junctions watertight, and the absence of soakers gives rise to much dampness finding a way into a building.

Object of Soakers

The object of using soakers is to arrest the passage of any water which may pass between the slates or tiles and conduct it towards the lower part of the roof. It is the practice in the cheaper class of work to omit soakers from the junction of the roof with party walls, and simply to make good by covering the joint with a fillet of cement. Fig. 7 shows the method of fixing soakers, also three ways in which the junction is made good. The use of soakers with a cement fillet is certainly better than omitting soakers altogether, but the correct job is to use a flashing over the upturned portion of the soaker, as shown.

Soakers Required

One soaker is required for each course of tiles or slates.

The Length of Soaker

This is equal to the margin or gauge plus the lap, plus 1 in. for nailing. To determine the length of soaker required: Deduct the lap from the length of the slate, divide the result by two, and add 4 in.

Example.—24-in. by 12-in. slates, laid to a 3-in. lap. ∴ 24 in. — 3 in. = 21 in., and

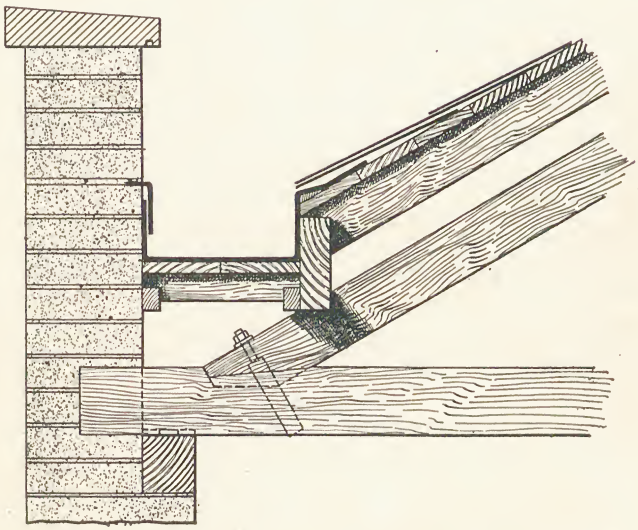


Fig. 16.—SECTION OF BOX GUTTER BEHIND PARAPET WALL

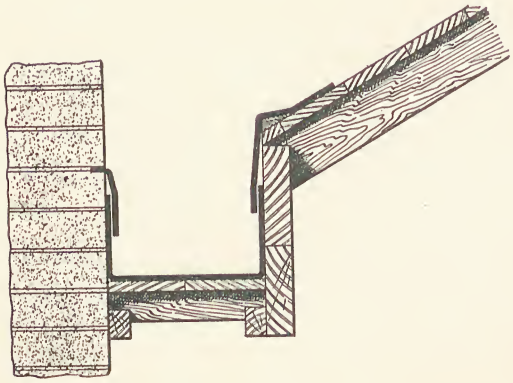


Fig. 17.—SECTION OF DEEP BOX GUTTER BEHIND PARAPET

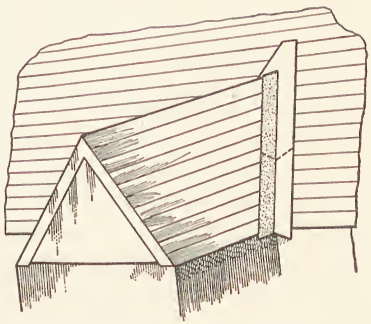


Fig. 18.—VALLEY GUTTER

$\frac{21}{2} = 10\frac{1}{2}$ in., and $10\frac{1}{2}$ in. + 4 in. = $14\frac{1}{2}$ in., length of soaker required.

The gauge in the above case would be $10\frac{1}{2}$ in., ∴ by the first statement $10\frac{1}{2}$ in. + 3 in. + 1 in. = $14\frac{1}{2}$ in.

Chimneys

The ways in which a roof may be constructed are so many that it would require a treatise to deal with them all and the methods adopted to render the junctions watertight. In the simplest form of roof, with overhanging eaves, there are usually one or more chimneys which require a gutter and flashings of metal. It has been stated that this may be of lead, copper, or zinc, and it does not matter which of these metals is used, the main principles are the same. Fig. 8A shows a section through a small stack, and the arrangement of the gutter or chimney back and the front apron. The principle adopted for weathering the sides is similar to that shown in Fig. 7, i.e. with soakers and stepped flashing, or as shown in

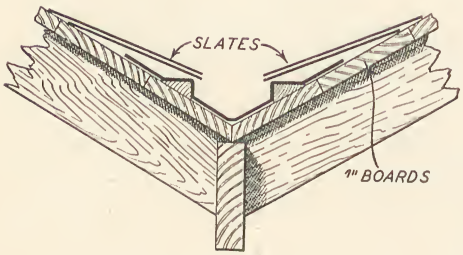


Fig. 19.—SECTION OF OPEN VALLEY GUTTER

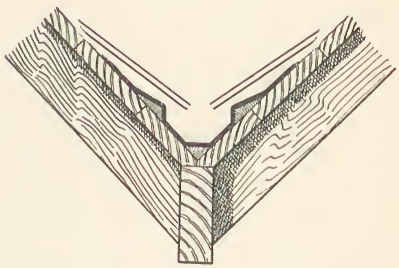


Fig. 20.—SECTION OF SECRET VALLEY GUTTER

Note use of small angle fillet.

Fig. 8B, with step-and-cover flashing. If copper is the metal being used, the chief difference in construction is the provision of an angle fillet to the gutter, as shown in Fig. 9.

Secret Gutter

In some cases, a secret gutter is used to weather the sides of a stack, as shown in Fig. 10. This method is often adopted for skylights and dormers. Where a flank wall cuts a sloping roof at an acute angle, the use of a secret gutter is necessary to prevent water entering the roof. Soakers would be unsuitable in a case of this description (Fig. 11).

Another Form of Roof Junction

Another form of roof junction with brickwork is shown in Fig. 12, and this shows a slated slope finished at the top against a wall.

Built-up Gutters

These are mainly of two types—box and tapering. They are formed where a roof is constructed with a parapet wall, or between two sloping roofs forming a valley (Figs. 13, 14, 15, 16, and 17), and these may be lined with lead, copper, zinc, or asphalte. In the case of a long gutter with a metal lining, proper drips must be formed in the length, but with an asphalte lining these are unnecessary. If, however, it is desired to form drips for asphalte, no joint is necessary, the material simply forming a ramp. Where an asphalte-lined gutter discharges into a rain-water head, a sheet-lead apron is used at the edge and the asphalte laid and dressed over it.

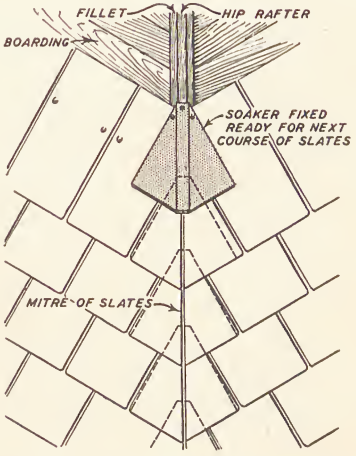


Fig. 21.—METHOD OF WEATHERING A HIP WITH SOAKERS

Valleys

These are formed where two sloping roofs intersect (Fig. 18), and Figs. 19 and 20 show two methods of lining them.

Hips

These may be rendered watertight by the use of hip tiles, metal coverings, or soakers.

Fig. 21 shows the method of weathering a hip with soakers.

QUESTIONS AND ANSWERS

What are the standard methods of protection for a Wall in a very exposed position where it is likely to suffer from the effects of Driving Rain ?

(1) A cavity wall with a well-ventilated air space between an outer skin and the inner wall.
(2) A vertical damp-proof course constructed within the wall.
(3) Facings of glazed bricks or similar materials.
(4) Cement rendering.
(5) Rough-cast.
(6) Tile hanging or slate hanging.
(7) Asbestos-cement sheeting fixed in panels.

What different types of Roofing Materials are suitable for Domestic or Industrial Premises ?

Asphalte, slates, asbestos slates, pan tiles, asbestos-cement tiles and sheets, clay tiles, thatch, cement, lead, copper, zinc.

What is a Double Eaves Course ?

This is the first course of slates, laid at the lower portion or " eaves " of a roof.

What are the usual methods of preparing Roofs for Slating or Tiling ?

(1) By nailing the battens to the rafters and then fixing the slates or tiles without further protection.
(2) By lining the under side of the roof with grooved and tongued boarding to keep the roof space free from dust and draughts.
(3) By laying close boarding on the rafters, and covering this with sarking felt as slating proceeds. For tiled roofs the battens are fixed over the felt. The latter method is adopted in most good-class work.

What are the three methods of finishing Slating where it abuts on a Party Wall ?

(1) By using a cement fillet only—cheap and incorrect.
(2) By using a cement fillet with soakers—an improvement over method (1).
(3) By using soakers and stepped flashing—the correct method.

How would you determine the length of Soaker required ?

Deduct the lap from the length of the slate, divide the result by two, and add 4 in.

USEFUL DATA ABOUT COPPER PIPES

THE low frictional resistance offered to the flow of water passing through pipes of copper permits the use of small-diameter pipes for many purposes, with a consequent saving in installation costs, coupled with a neat appearance.

Rusting

As copper pipes do not rust, discoloration of water passing through them, and the reduction of the flow due to the restriction of the bore, are avoided. Externally, protection is not required.

Strength

As the tubes are solid-drawn, they are of a very high tensile strength. This permits the use of tubes with very thin walls ; hence the term "light-gauge tubes." The weight in pounds per foot of a $\frac{3}{4}$-in. bore 19 S.W.G. copper tube is ·38, and the wall thickness is ·040 in., as compared with a $\frac{3}{4}$-in. bore lead pipe weighing 3 lb. per foot which has a wall thickness of ·203 in. A $\frac{3}{4}$-in. iron tube of steam strength, weighing 1·403 lb. per foot and of 9 S.W.G., has a wall thickness of ·144 in.

L.C.C. WEIGHT OF COPPER SOIL, WASTE, AND VENT PIPES

Internal Diam. in in.	*Weight per yard not less than*	*Internal Diam. in in.*	*Weight per yard not less than*
$1\frac{1}{4}$	2·25 lb.	$3\frac{1}{2}$	9·33 lb.
$1\frac{1}{2}$	2·7 lb.	4	11·85 lb.
2	4·17 lb.	$4\frac{1}{2}$	13·29 lb.
$2\frac{1}{2}$	5·19 lb.	5	14·76 lb.
3	7·11 lb.	6	17·64 lb.

NOTE.—These are minimum weights, and will not be suitable in all circumstances. In determining the weight to be used, regard should be had to (*a*) the strength of pipe needed to resist the internal working "head" or pressure, and (*b*) the possibility of such pipe being used for the conveyance of hot liquids.

Corrosion

This is the attack by water on metal, and is dependent upon the nature of both water and metal. Copper possesses very high corrosion-resisting qualities and is therefore a useful material to use for water tubes. Hard water has practically no action on the commoner metals : a protective coating is formed within pipes conveying hard water by a deposit of lime, which prevents further action. In the case of soft

waters, iron and lead pipes are liable to attack, but copper pipes are not affected by soft water unless the latter is of an acid character. In such a case the water must be treated to neutralise the effect of the acid.

Frost Burst

Although copper tubes possess qualities which prevent them bursting except at high pressures, precautions should be taken to protect them from frost, and the following hints are suggested :—

Avoid making sharp bends.

Avoid making a sudden reduction in the bore of pipes by the insertion of reducing fittings.

Avoid long, continuous runs of pipe which are likely to be attacked by frost in whole or in part.

Pipes in roof spaces and all exposed positions should be wrapped in a suitable non-conducting material.

Avoid running pipes in roof spaces near to the eaves, as at this point they are very liable to attack.

Pipes run on the inner faces of external walls should be fixed to a wood ground, which acts as a non-conductor.

Arrange the installation so that the whole of the pipes can be easily drained down when necessary.

COPPER TUBES

STANDARD GAUGES FOR LIGHT COPPER TUBES AS PER MINISTRY OF HEALTH MODEL SPECIFICATION

Bore of Tube	*Thickness, S.W.G.*	*Weight per ft. in lb.*	*Bore of Tube*	*Thickness, S.W.G.*	*Weight per ft. in lb.*
$\frac{1}{8}$ in.	19	·08	$1\frac{1}{4}$ in.	17	·88
$\frac{1}{4}$ in.	18	·17	$1\frac{1}{2}$ in.	17	1·05
$\frac{3}{8}$ in.	18	·25	$1\frac{3}{4}$ in.	16	1·40
$\frac{1}{2}$ in.	18	·32	2 in.	16	1·60
$\frac{5}{8}$ in.	18	·39	$2\frac{1}{2}$ in.	16	1·98
$\frac{3}{4}$ in.	18	·46	3 in.	15	2·68
$\frac{7}{8}$ in.	18	·54	4 in.	13	4·55
1 in.	17	·71			

Weight in pounds of 1-in. copper pipe = the thickness of one wall × (bore of tube + thickness of one wall) ; all the dimensions being expressed in inches and decimals of an inch, and the result coming in pounds and decimals of a pound.

(*Copper Development Association*).

Care of Tubes Previous to Use

Copper tubes should be kept where they will not be damaged by other material being thrown against them.

Iron barrel is not harmed by rough use, excepting damage to threads, but copper is easily indented. Such indentations are very difficult to remove, even in the largest sizes used in buildings. Damage to the smaller sizes invariably means consigning the damaged portions to the scrap heap, with consequent loss.

THE DRAINAGE OF BUILDINGS

PART III.—INSPECTION CHAMBERS, MANHOLES, PIPE LAYING, ETC.

INSPECTION chambers, sometimes called manholes (Fig. 1), are required on drains for cleaning, testing, and general access. It should be possible to run cleaning rods through every pipe on the system ; and it should also be possible to insert a plug in the end of every pipe, so that it can be filled with water, or with air or smoke under pressure, for testing purposes. Thus manholes must be provided on any long, straight length of drain, at such intervals as to make cleaning with rods an easy matter. The rods can be passed through very long lengths of drain, but the labour of doing so is dependent upon the condition of the pipe and its diameter ; also, as the work proceeds and additional lengths are connected to extend the rod, the labour of moving it along the drain becomes greater and greater. If a pipe is badly clogged, the labour of forcing a rod with a scraper, brush, or other tool fixed on the end becomes very great on a long length. Thus, on a 4-in. drain it is well to have manholes not more than 100 ft. apart. On a 6-in. drain this distance may be increased considerably, but even on a 9-in. drain the maximum distance apart for manholes is generally taken to be 300 ft.

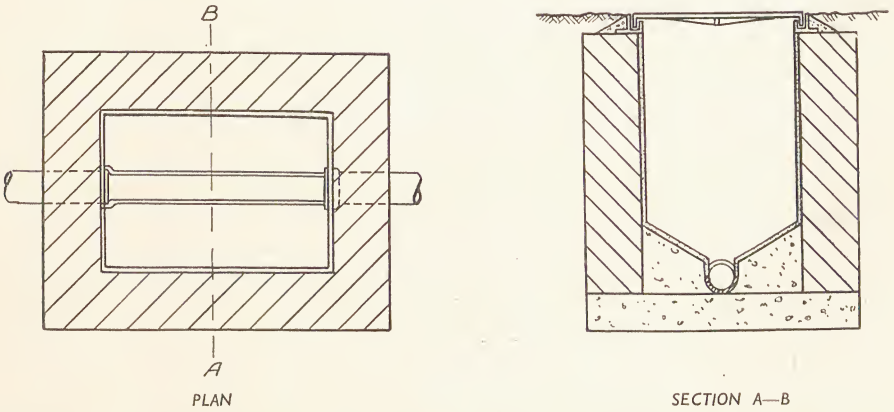


Fig. 1.—A TYPICAL MANHOLE ON A STRAIGHT LENGTH OF DRAIN WITHOUT BRANCHES, 3 FT. 6 IN. DEEP

With large cover, allowing easy access to the drains.

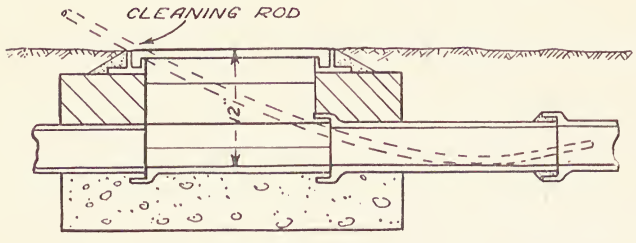
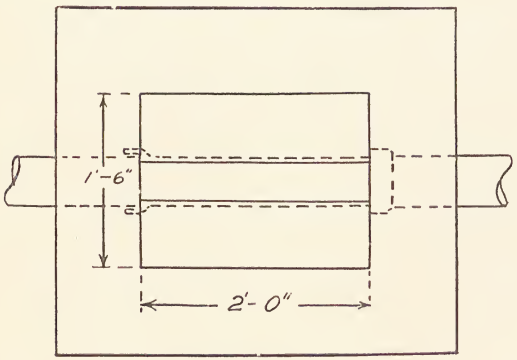


Fig. 2.—SMALL MANHOLE, 12 IN. DEEP

To invert on a straight length of drain without branches this may be of very small size, and yet provide access to the drains.

Where Manholes Are Needed

It is necessary that a manhole should be made where any branch drain joins a main drain. It is also necessary to provide a manhole where any change of direction occurs, for the reason that rods cannot be passed so easily through bends, and also because drains are more likely to become blocked where bends occur, and it is therefore desirable that facilities should be provided for cleaning at such points. If there is any decided change of gradient at any point along the course of the drain, it is customary to provide a manhole at that point, for the same reason. Finally, a manhole must be provided where the trap exists which intercepts the house drains from the main sewer.



Thus it will be seen that manholes must be provided at the following places :—

(*a*) Where any junction occurs.

(*b*) Where any change of direction occurs.

(*c*) Where a change of gradient occurs.

(*d*) On any long, straight line of drain through which rods could not otherwise be passed easily.

(*e*) Where the interceptor trap occurs.

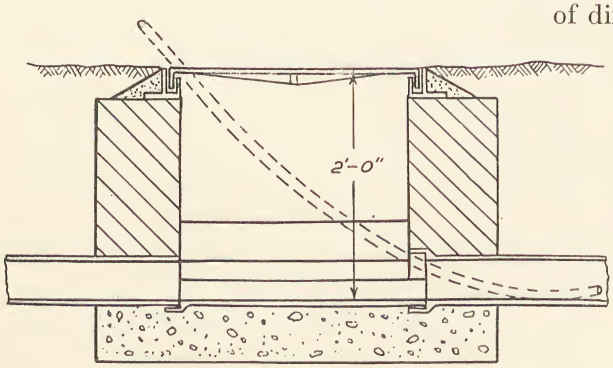


Fig. 3.—MANHOLE, 2 FT. DEEP

Showing how the cleaning rod can be manipulated from the top.

Designing a Manhole

In designing a manhole, its use

must be carefully considered. Where the drain is deep, the inspection chamber must be large enough to allow a man working in it to manipulate rods and to insert plugs in any of the drains connected to the manhole. Where the manhole is shallow, however, it is clear that a man cannot work inside it for lack of head-room, and as all cleaning must be done from ground level, it is well to make the manhole as small as possible in plan. In the case of the deep manhole, a man can pass through an opening, namely, the frame of the manhole cover, say 1 ft. 6 in. by 2 ft., or 21 in., square, but it may sometimes be necessary to provide a larger cover for the shallow manhole, or possibly two covers side by side, in order to enable the workmen to reach the drains easily.

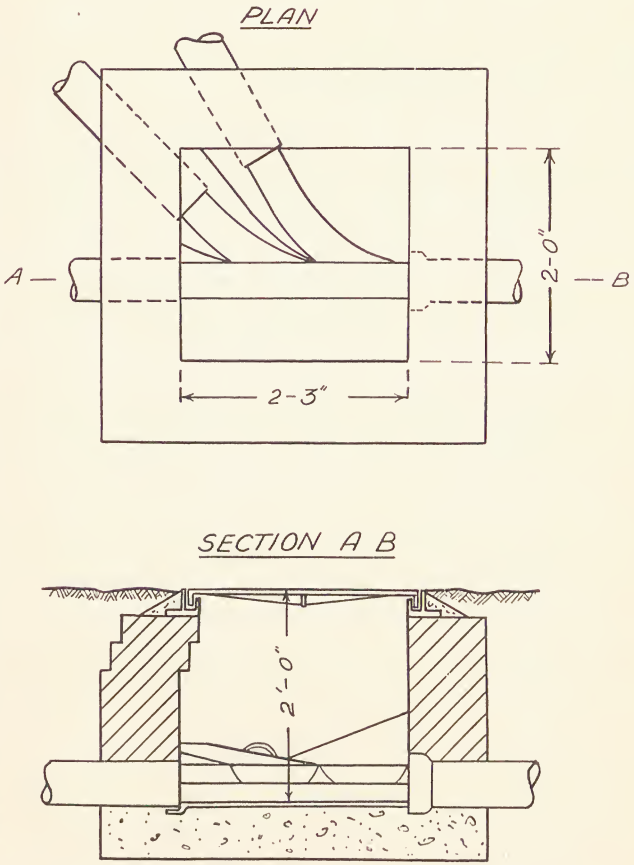


Fig. 4.—MANHOLE 2 FT. DEEP, WITH SIDE CHANNELS Requiring greater breadth, so as to make cleaning with rods possible.

In many ill-designed systems it will be found that while the deep manholes are of such a size as to cramp the men working in them, or even to make work impossible, the shallow manholes are unnecessarily large. The extra cost of making the deep manholes, which are generally few in number, of proper size is more than balanced by the saving to be effected in making the shallow manholes of proper size.

In the practice of the present writer, the deeper manholes are generally made 4 ft. in length by 2 ft. 3 in. in width in the clear. For shallow smaller manholes, it is specified that the pits shall be large enough to provide comfortable access for inspection and cleaning, but that they

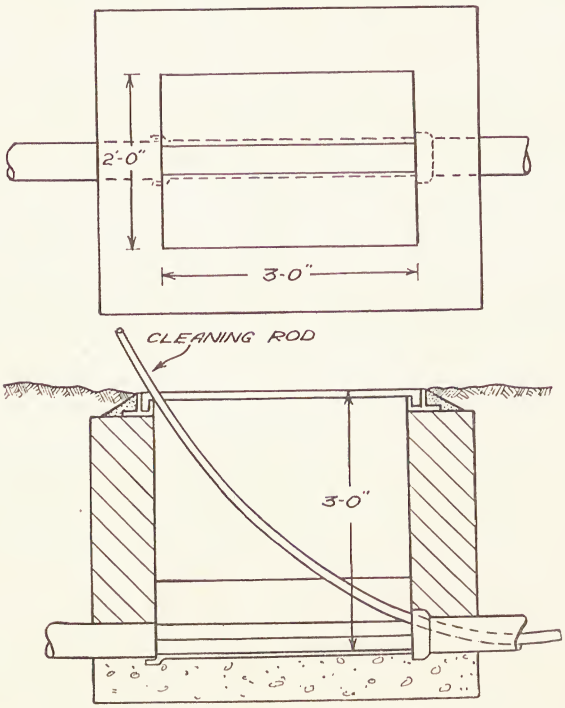


Fig. 5.—MANHOLE, 3 FT. DEEP

Showing manipulation of cleaning rods from the surface.

are to be made no larger and no smaller than may be necessary for that purpose.

Size of Manholes

With regard to the size of manholes, one should bear in mind the reason for which they are required; for example, a drain may be very shallow, say 12 in. deep, at the head of a drain. Clearly all that is required in such a case is a small opening for access (Fig. 2), in the nature of an inspection eye, placed in a pit and provided with a suitable cover, and under such circumstances an 18-in. or even a 12-in. square cover may sometimes be sufficient, the manhole being of the same size as the cover. If the manhole is deeper, say 2 ft. to the invert, it can probably be made, say, 2 ft. long by 1 ft. 6 in. wide, as will be seen in Fig. 3. A drain rod could be passed into the drain without much trouble in a manhole of this size if it occurred on a suitable drain.

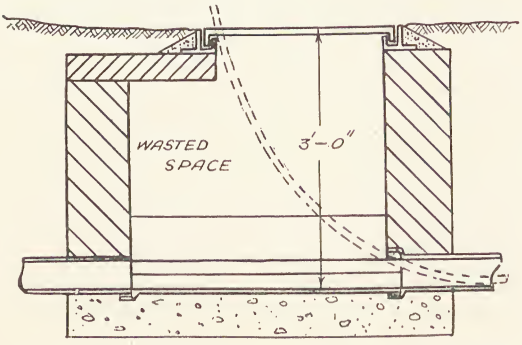


Fig. 6.—MANHOLE, 3 FT. DEEP, WITH COVERED PORTION

This is unsatisfactory owing to roofing and small cover. Note the cleaning rod is bent beyond its safe limit.

It is possible, however, that greater length might be desirable, and greater width if there were side branches (Fig. 4). If the manhole were 3 ft. deep, it would probably be necessary to make it 3 ft. in length by 2 ft. in width (Fig. 5). It will be observed that it is quite useless to make a

shallow manhole of large size in plan, if a large part of it is roofed over (Fig. 6). This mistake is apt to occur when some special size is specified for all shallow manholes irrespective of conditions.

In order that a man may be able to work comfortably in a manhole, it is necessary that he should have at least 4 ft. of head-room (Fig. 7); if this space is diminished to, say, 3 ft., working will be difficult, and with less, practically impossible. It is true that manholes are often made of smaller size, but it is false economy to make the working space such that the labour involved in carrying out any drain-cleaning work or testing will be greatly increased.

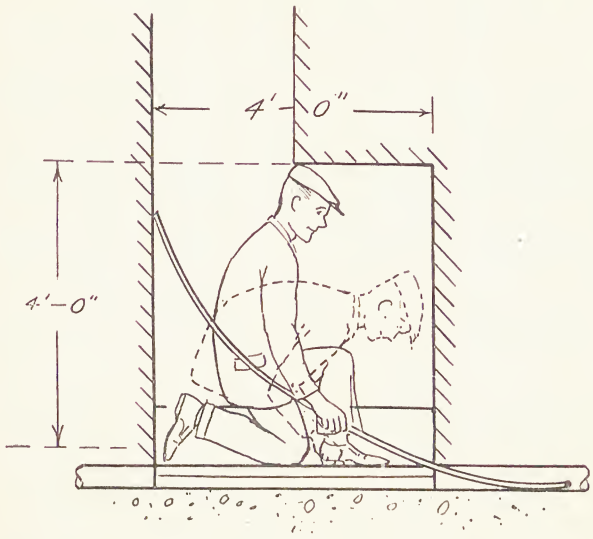


Fig. 7.—A MANHOLE MUST BE LARGE ENOUGH TO ALLOW WORKING SPACE

Position of Drains

Much depends upon the position of the drains and the number of the branches entering the manhole, and also upon the position of the manhole cover in the case of manholes of shallow depth. The manhole must, therefore, be designed taking all these points into consideration. Where long branches occur at anything approaching a right angle, it is sometimes necessary to provide a pocket in the side of the manhole (Fig. 8), in order to allow for the proper working of the rods.

Manholes are constructed of brickwork in cement, concrete, or masonry. Ready-made concrete tube manholes are also used, especially in larger work (Fig. 9). Cast-iron manholes, which will be described later, are also used, especially where iron drain pipes are used.

The inlet and the outlet drains of the ordinary manhole are connected to glazed

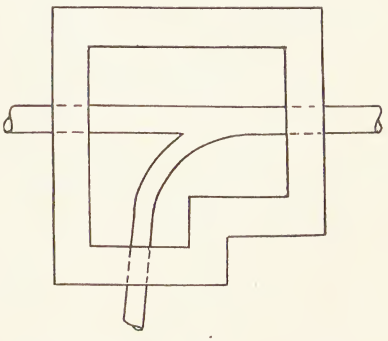


Fig. 8.—MANHOLE WITH POCKET

Where a branch drain occurs, a pocket in the manhole may be needed in order to provide proper working space.

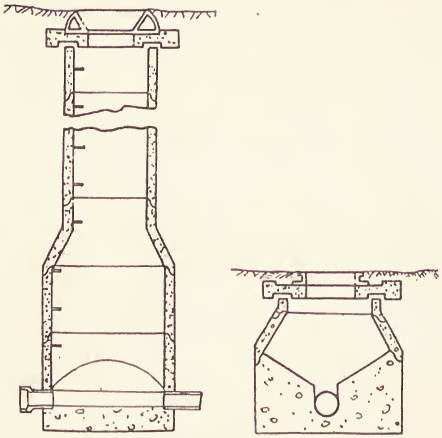


Fig. 9.—CONCRETE MANHOLES

Manholes formed of concrete tubes with ready-made bases are useful, particularly in wet ground. The joints are made with cement.

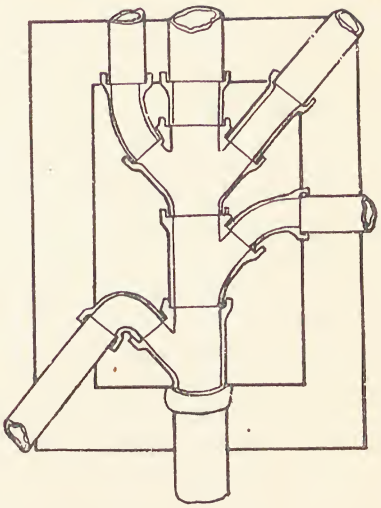


Fig. 10.—BRANCH DRAINS ON THE SAME LEVEL AS MAIN DRAIN ARE CONNECTED TO BRANCH CHANNELS

half-pipe channels. Junction pipes are connected to Y-junctions on the channel pipes by means of branch channels inside the manhole between the pipe and the main channel (Fig. 10). These generally occur where main branches join, but the short branches are connected to side inlet channels which discharge above the lip of the main channel if the fall permits (Fig. 11).

In construction, the bottom of the excavation is covered with 6 in. of concrete for its full width, the channels are bedded carefully in cement on this concrete and are jointed carefully in cement.

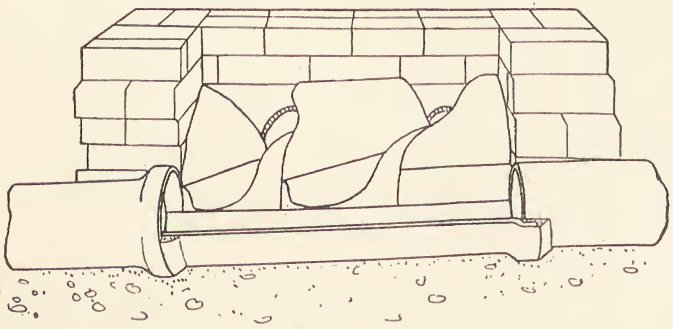


Fig. 11.—BRANCH DRAINS WHERE THE FALL IS AVAILABLE ARE TAKEN IN BY MEANS OF SIDE CHANNELS DISCHARGING OVER MAIN CHANNEL

Where Drain Pipes Pass through Manhole Walls

Where the drain pipes pass through the manhole walls, they are surrounded by 2 to 1 Portland cement mortar, so as to make a good joint with the interior lining.

Care must be taken to make the pipe spigots fit properly into the sockets of the channel pipes, and also to make the spigot of the outlet channel fit exactly into the socket of the drain pipe (Fig. 12). Where iron pipes are used in drainage, a special iron-to-stoneware connecting pipe has to be jointed to the drain; this is a short iron pipe having a socket similar to that on a stoneware pipe, so that a cement joint can be made between the channel and the iron pipe (Fig. 13). It is difficult to make a proper joint between a stoneware pipe or channel and an ordinary iron socket.

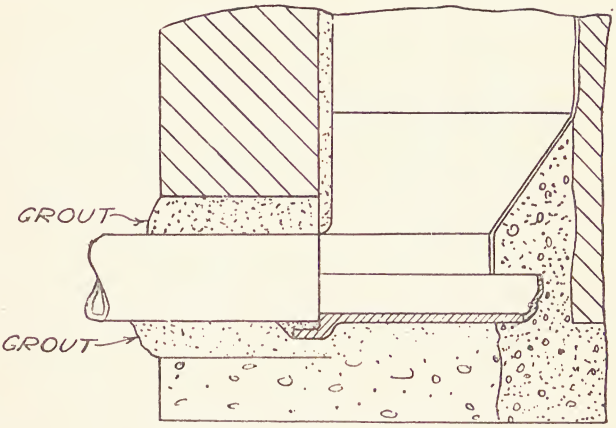


Fig. 12.—When a pipe passes through a manhole wall it should be surrounded with cement mortar, and channels should be similarly bedded in cement

When the channels have been bedded, concrete is built in above the foundation already laid, being well tucked under the channel pipes; boards are then inserted above the edges of the main channel, and concrete benching is laid up to the level of the soffit of the main drain pipes, and the benching is sloped off towards the sides of the manhole at an angle of about 30° to the horizontal (Fig. 14). Concrete is filled in and shaped round the side channels; the object of this benching is that any sewage splashed on to it may run back into the main channel, and that there shall be no space where any foul matter or sewage can accumulate.

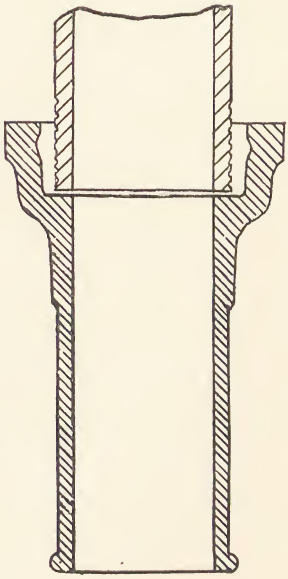


Fig. 13.—Stoneware-to-iron connecting pipe

The joint is made with cement.

Interior Surfaces

The interior surfaces of the concrete above the channels of the benching and of the manhole walls are rendered with ½ in. of 2 to 1 cement mortar. This work must be done very carefully, as upon it will depend the watertightness of the manhole. The surface of the concrete

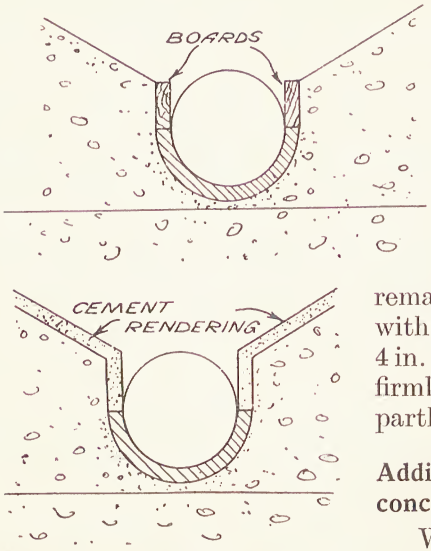


Fig. 14.—IN FORMING MANHOLE BENCHING, BOARDS ARE USED FOR THE SUPPORT OF THE CONCRETE

or brickwork must be carefully cleaned and saturated with water before the cement is applied. The rendering should be applied and finished in one coat, and should be trowelled to a smooth face. After it has set for some days it should be rapped all over, and any places which sound hollow should be cut out and remade. The manholes are partly covered with stone slabs or with reinforced concrete 4 in. thick, and the cover frames are bedded firmly in cement, partly on the walls and partly on the stone or concrete covers.

Additional Support by Means of Reinforced-concrete or Steel Joists

Where heavy traffic is expected, additional support in the nature of reinforced concrete, or steel joists encased in cement, must be provided. In the deeper manholes, malleable step irons, coated or galvanised, are built into the walls, so that there may be no difficulty of access to the interior ; they should be grouted round carefully, as in the case of pipes passing through the walls, so that the rendering may make a good joint (Fig. 15). Leakages at step irons are common ; cast-iron step irons may be dangerous as they may break suddenly, whereas malleable step irons if overloaded will only bend.

The manhole walls are built of 9-in. brickwork in cement mortar, but where very shallow manholes occur, 4-in. concrete walls are sometimes considered to be sufficient ; while in the case of reinforced-concrete structures, a 4-in. wall may be sufficient for deeper manholes.

It is customary to build up the benching in the manhole and to render this work before the upper part of the manhole has been built ; the cement work must be done very carefully, and the bricklayer or plasterer will need all the working space available. When this work has been done, boards are placed above it, forming a platform which protects the lower work, upon which the bricklayer stands to build up the walls (Fig. 16).

The side inlet channels should not be cut, as they are formed with a special edge for fitting exactly on to the main channels (Fig. 17). On the other hand, the plain straight channels can be cut in case of need. The work is generally done with a blunt hand-saw and sand. If the manholes are drawn out in detail so that the channels can be chosen before the work is done, there should be no need for cutting. The channels

can be ordered as shown on the drawings, and can be marked and numbered so that they can be fitted exactly into place when they arrive on the work. If this is done, and if the work has been carefully set out, there should be no trouble in arranging the manholes, and a great deal of time, labour, and expense will be saved. Finally, if it is not possible to provide a glazed channel in any particular place, a perfectly good channel can be formed in cement.

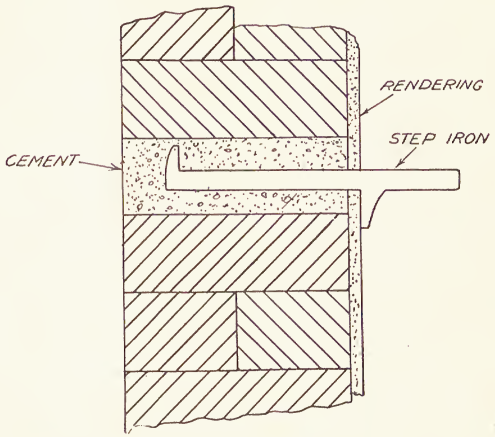


Fig. 15.—STEP IRONS SHOULD BE GROUTED IN WALLS SO AS TO PREVENT LEAKAGE

On bends in main channels, the benching should project slightly over the channel on the outside of any curve, in order that the sewage may not be thrown up on to the benching by centrifugal force (Fig. 18). The same may be necessary in front of side inlets, so as to prevent any solid matters from being thrown up on to the benching.

Interceptors

In setting an interceptor in position, it is necessary to place it on a level base, because a tilt will reduce the water seal. Stoppers to interceptor cleaning-eyes are a source of trouble unless care is taken. Sometimes the stoppers and their sockets are coated with bitumen, and the stopper is merely slipped into the eye ; under such conditions, the stopper may be blown out by pressure of air from the sewer. When stoneware stoppers are cemented in place, they must be broken when any cleaning of the pipe running from the trap to the sewer has to be done, and it is very possible that no new stopper will be at hand, in which case it will probably be left out, so that the seal becomes inoperative. Sometimes a loose stopper falls into the interceptor trap and causes a blockage, in which case the drainage system fills with sewage up to the level of the cleaning-eye, through which it will then flow. The stored sewage will become very foul and septic, and the condition may not be discovered for an indefinite period (Fig. 19). For this reason, it is very desirable that a good, metal, locking cleaning-eye stopper should be provided. If this cannot be done, a simple piece of slate fastened in place with a fillet of cement is preferable to the stoneware stopper, because it can always be replaced easily (Fig. 20).

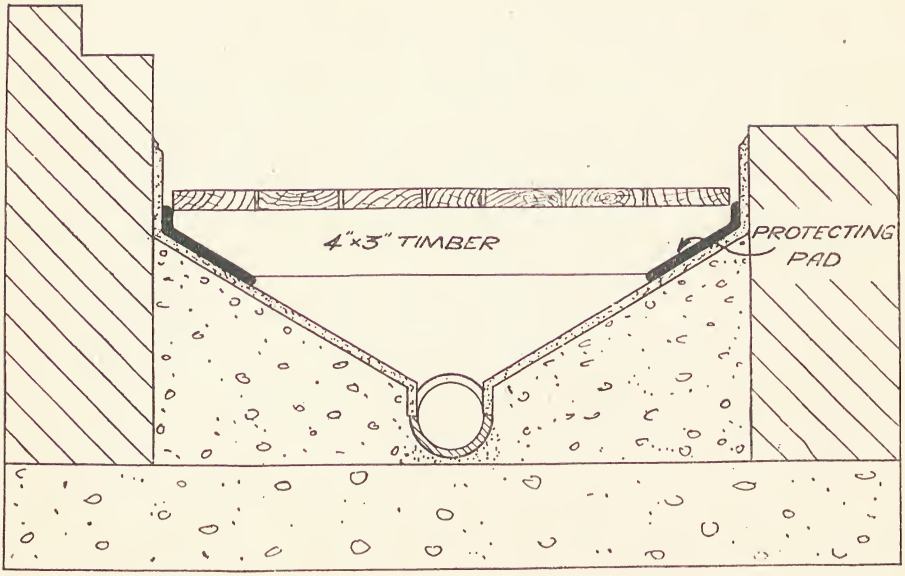


Fig. 16.—PLATFORM FOR BRICKLAYER

Ventilation pipes are connected to manholes at a high level, although soil and vent-pipes connected to drains must enter the manhole by connection to ordinary channels.

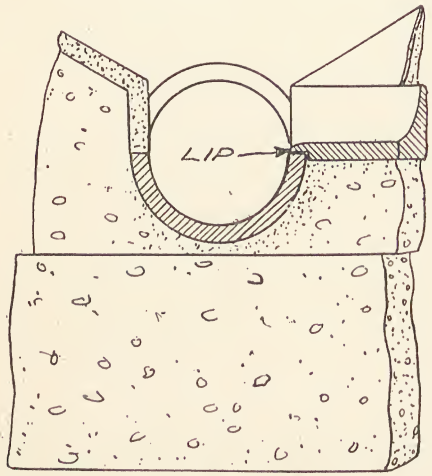


Fig. 17.—SECTION SHOWING SIDE CHANNEL WITH LIP, WHICH MUST BE FITTED EXACTLY OVER THE MAIN CHANNEL

Concrete Manholes

Concrete tube manholes (Fig. 9) are particularly useful for deep work. When the ground is waterlogged they may be useful, as they are watertight. The base can be obtained ready made with channels at any required angle. All that is necessary is to send a sketch to the makers, showing the angles required. The manhole base is provided with pipes fixed in place, to which connections can be made. For shallow manholes, special types are provided. For deep manholes, the step irons are supplied ready fixed in place.

Iron Manholes

On iron drains, which are becoming very common for house drainage, the manholes can take the form of ready-made hatch-boxes, which are later described (Fig. 21).

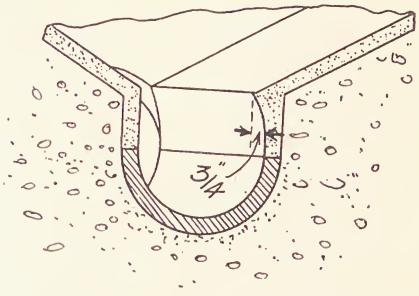


Fig. 18.—BENCHING PROJECTING OVER CHANNEL ON BEND

Cleaning-eyes (Fig. 22)

With regard to cleaning-eyes and inspection eyes on drains, speaking generally it is best to build manholes, for the reason that the drains can then be cleaned more easily than from a cleaning-eye, as there will be less difficulty in forcing drain rods through any considerable length of drain when there is a fair-sized opening to work from. Also, the device is suitable only on a straight pipe-line of no great depth. When junctions occur, manholes are required. The existence of small covers, which are to be used with cleaning-eyes, is likely to be forgotten.

Covers

There are very many kinds of manhole cover, suitable for different conditions, as may be seen in makers' catalogues.

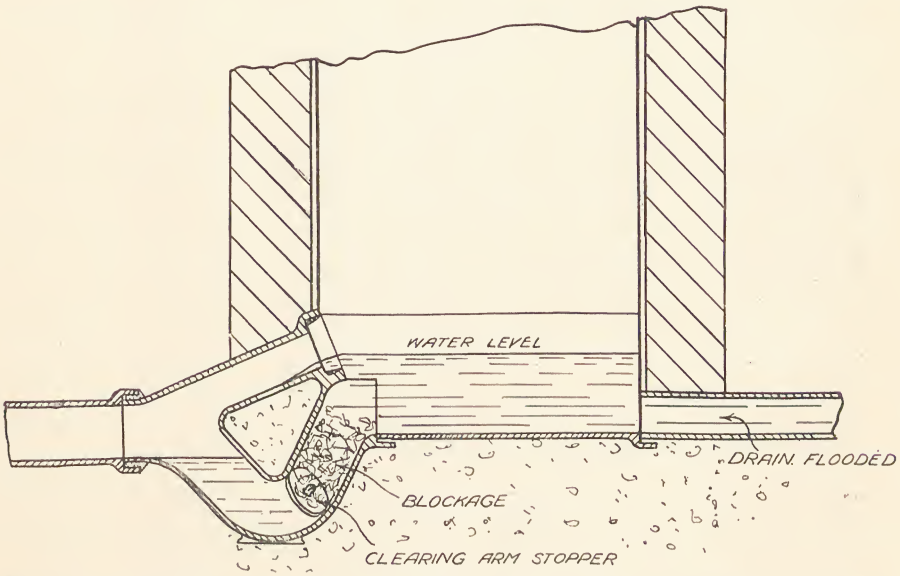


Fig. 19.—DRAINAGE SYSTEM FULL AND OVERFLOWING THROUGH INTERCEPTOR CLEARING
Note the stopper of the cleaning-eye has fallen into the trap and has blocked the drain.

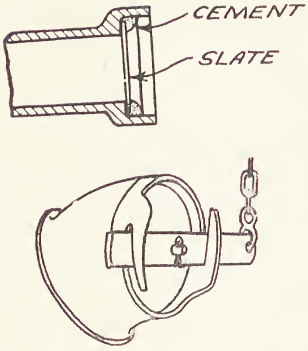


Fig. 20.—SLATE AND CEMENT FILLET IN CLEANING-EYE OF INTERCEPTOR, AND METAL CLEANING-EYE STOPPER

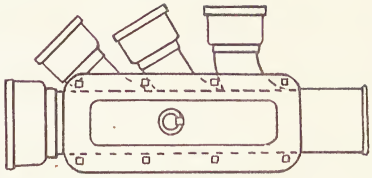


Fig. 21.—HATCH-BOX FOR IRON DRAIN

Very light covers are used on cheap work, but they are not suitable for good work as they are likely to be cracked or broken. The position of the manhole, its depth, and the nature of the surrounding ground must decide the size and type of cover to be used. The ordinary cover is made with a single seal; that is to say, the frame is provided with a groove $1\frac{1}{2}$ in. deep all round, and into this groove fit the edges of the cover, made at right angles to the surface, leaving a space which is generally filled with tallow or with some special composition. Thus the seal is airtight (Figs. 23, 24, 25, and 26). Such a seal is generally provided for covers near houses, but where they are farther away, reliance is placed upon a water seal; that is to say, the rain-water fills the groove and forms a water trap. When covers are in places remote from the house, where an occasional outlet of air from the drains would not be objectionable, covers are sometimes provided with ventilating openings.

If a cover exists at a place where carts or traffic may come upon it, special strength is necessary, and heavier covers must be provided. The possibilities of traffic vary considerably; for instance, on a pathway leading up to a front entrance of a house it is possible that barrows, trucks, or light vehicles might require a cover of greater strength than would be needed only for foot traffic, but on a pathway leading to the kitchen quarters, where it is possible that coal carts and lorries might come, a cover of road strength is required (Fig. 26).

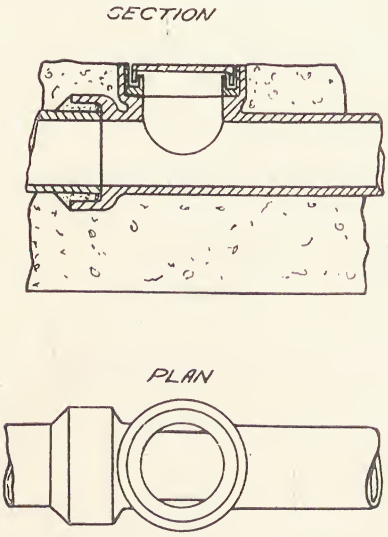


Fig. 22.—CLEANING-EYE ON DRAIN

It is very undesirable that any manhole cover should be hidden, and for this reason the practice of covering them with gravel on paths should be discountenanced if possible.

Covers are provided with recessed tops, which can be filled with concrete,

gravel, or other material to match the surrounding ground (Fig. 25). Inside buildings, when covers occur in tiled floors, they can be filled with tiles to match the floor, and so forth.

Fig. 23.—SECTION OF SINGLE-SEAL MANHOLE COVER

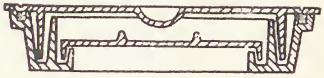


Fig. 24.—SECTION OF DOUBLE-SEAL MANHOLE COVER

When covers occur inside buildings, great care has to be taken that they should be perfectly airtight, and they are therefore provided with double seals; sometimes the inner seal is charged with water by condensation. Covers are also screwed down on to gaskets or washers. These covers inside a building should always be of best quality (Fig. 24).

Covers are painted, coated with Dr. Angus Smith's solution, or galvanised. The galvanised-iron cover is to be preferred, if only for the reason that it does not get rusted into the frame. Lifting-hooks and keys are provided for covers according to the type used. Where a long manhole cover is required, two or three covers are sometimes fitted into one frame.

In deep manholes constructed of brickwork, the roof is sometimes formed of a semicircular brickwork arch with a shaft rising to the surface. The minimum size of this shaft is 2 ft. by 2 ft. in the clear.

PIPE LAYING

As several kinds of pipe are used in drainage work, and as the conditions under which they have to be laid may vary within wide limits, involving the use of special joints, special foundations, and special protection, together with the use of particular fittings and appliances, it is evident that no standard specification can be prepared which is applicable to all cases. There are, however, certain main characteristics in all drainage work, and a standard specification may therefore be helpful if it is followed intelligently. Such specifications have been published, but they should not be followed blindly.

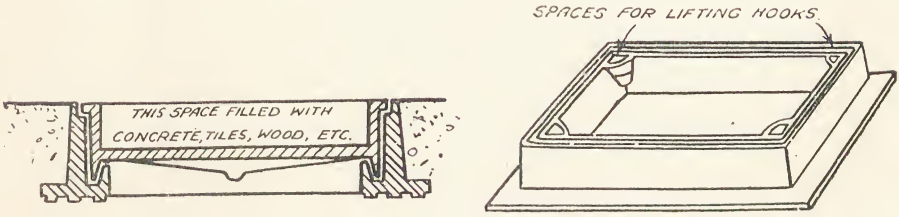


Fig. 25.—RECESSED MANHOLE COVER

Fig. 26.—SECTION OF HEAVY ROAD COVER

In order to describe ordinary pipe-laying methods, certain quotations from specifications which have been used by the present writer on various works are given below.

The length of the specification will naturally be dependent upon the amount of work to be described. For very small works of simple character, much that is necessary in the case of larger and more difficult work may be omitted from the specification, but a glance through the standard will tend to prevent the omission of any matter of importance. Long specifications, containing unnecessary matter, are to be avoided.

The Specification

It is well to preface the specification by a statement of the general requirements, such as compliance with the local by-laws; and to give general particulars, such as a list of drawings referred to in the specification, a description of the catalogues of any special goods or materials required on the work, the penalty for non-completion, the name of the person or authority for whom the work is to be carried out, instructions as to the preparation and presentation of accounts, the terms of payment, and so forth.

Having given this general description of work, the details of construction follow.

CONSTRUCTIONAL WORK FOR TRENCHES

(1) The pipes are to be laid to the alignment and gradients shown on the accompanying plans and sections, but subject to any modification ordered in writing.

(2) The trenches are to be made with a true gradient throughout, and are to run in perfectly straight lines at their proper levels by the aid of sight-rails which are to be used at the beginning and at the end of each trench. The excavations are to be of such lengths and of such width as shall, in the opinion of the engineer,[1] be necessary for the proper construction of the drains.

(3) In excavating the trenches, the gravel of paths, pavement slabs, turf, or other material forming the surface of the ground is to be placed on one side and preserved for reinstatement after the trench has been filled in. The turf is to be cut in strips, rolled up, and stored in the shade.

(4) The trenches are to be excavated to such a depth that the pipes may rest on concrete, as described in the several clauses relating thereto, and so that the inverts may be at the levels given on the sections. In bad ground, the engineer may order the contractor to excavate to a

[1] Engineer, architect, or other person responsible for the design and execution of the work.

greater depth than that shown on the drawings, and to fill in the excavation to the level of the drain with concrete or other material. For extra excavation and concrete, arising from bad ground, the contractor will be paid extra, but if he should excavate the trench in good ground to a greater depth than is required, the extra depth will have to be filled up with concrete at the contractor's expense.

(5) The sides of the trenches and manhole excavations are to be supported by suitable timbering, and they shall be close timbered wherever the engineer may consider necessary, without extra cost. It is intended that the timbering shall be removed as the work proceeds, but the engineer may require any portion of it to be left in the ground if he considers it advisable. Such timbering left in will be paid for in accordance with the schedule of prices hereto annexed.

(6) The contractor shall provide and perform as part of the contract, all pumping, baling, and removal of water or sewage that may be required in executing the works, and in maintaining them free from sewage and water during the period of construction. No water or sewage shall be allowed to accumulate at any time.

Specification for Stoneware-drain Construction

(7) In trenches where ordinary spigot and socket pipes are used, a layer of 6 to 1 concrete 3 in. thick, the width being the external diameter of the pipe plus 6 in. on either side, is to be laid along the bottom of the trench, the surface being formed evenly to the required gradient. Bricks are then to be laid on the concrete bed, one behind each socket, to raise the pipes so that the outside of the sockets may be approximately 1 in. above the concrete bed, in order to allow for the joints being made properly on the under side. The pipes are to be laid sockets forward, beginning at the lower end, and they are to be supported temporarily, to prevent rolling, with small props of cement mortar (Fig. 27).

(8) After the joints and pipes have been proved to be watertight, concrete is to be filled in to the level of the tops of the bricks, and from this level the concrete is to be benched, being well tucked in under the pipes, as shown on the detailed drawing attached to this specification.

(9) The engineer may increase or diminish the concrete under or around the pipes, both as to quantity and quality, according to the nature of the ground that may be revealed when the trenches are opened out, and he will at the same time increase or diminish the amount of the contract proportionately at the rates and amounts contained in the schedule for extra works.

(10) The joints of ordinary spigot and socket pipes are to be made with neat cement, freshly gauged, and it must not be allowed to " go off " or be made up again. The cement must have been previously spread out in a layer 6 in. thick on a dry floor inside a building for nine days to be air-slaked, so that there may be no risk of cracking the pipe sockets.

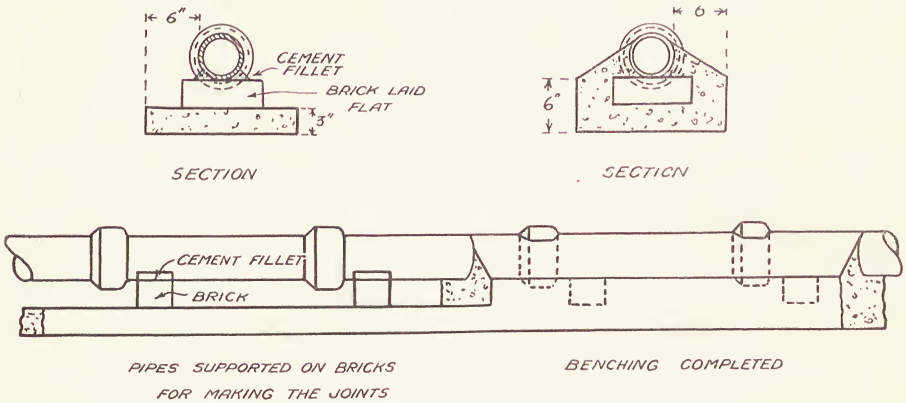


Fig. 27.—Detail showing the laying of a stoneware drain

Each joint must be thoroughly well filled, and the inside of the pipe must be carefully wiped out with a mop or scraper. There must be no proud edge of pipe projecting inside, or any fin or lump of cement, but the inside must be left perfectly smooth and clean. The outside of each joint must be finished with a trowelled face all round. Space must be left for examining the joints all round during the water test.

(11) After a sufficient interval has been allowed for the joints to set, the pipes are to be tested under a head of at least 3 ft. of water, and in no case under a greater pressure than that exerted by an 8-ft. head of water. The sewer must be proved to be perfectly watertight. Any defective spigot and socket joint must be cut out and made good, any cracked or defective pipe must be replaced.

Inspection Chambers

(12) Inspection chambers are to be built in 9-in. brickwork in cement mortar. The foundations for the walls and channels are to be of concrete (6 to 1), 6 in. deep. The whole of the inside of the chamber is to be rendered in 2 to 1 cement mortar $\frac{1}{2}$ in. thick, and finished with a trowelled face, so as to be quite watertight. The channels are to be of white glazed ware, and the side-channel bends are to be of three-quarter section. The sides of the channels are to be carried up vertically in cement to the level of the soffit of the drain, and where they face side inlets they are to be made to overhang about $\frac{3}{4}$ in.

(13) The shallow manholes less than 4 ft. deep are to be large enough to provide comfortable access for inspection and cleaning, but are to be no larger or smaller than is necessary for this purpose. Manholes of greater depth are to be 4 ft. in length and 2 ft. 3 in. in breadth (inside measurements), unless otherwise specified. The access shaft above the manhole roof is to be 2 ft. by 2 ft. square in the clear, and is to be constructed of 9-in. brickwork in cement.

GENERAL PRINCIPLES OF HOT-WATER SUPPLY

PART II.—THE DESIGN OF SECONDARY CIRCULATIONS

THE design of secondary circulations becomes more complicated when two or more branches are included. The simple circuit dealt with in the previous section would have some circulation whatever size is chosen for the return, within normal limits. When complex piping networks are considered, it is essential that the resistance to the flow of water be balanced by the circulating pressure to quite close margins. If this is not done by the proper choice of pipe sizes or regulation by valves, then some branches will be completely lacking in circulation. It may even be found, in some branches, that a reversal of flow direction has taken place. The water attempts to circulate from the return of favourable circuits back through the unfavourable circuits. The circulation does not, of course, get very far. The majority of the piping included in an unfavourable circuit will, in such a case, be completely cold.

The Downward-type System

In such cases each branch must be considered separately. The circuit must be so arranged that the friction and circulating pressure balance. Fig. 1 shows a small system of the downward type, such as might be installed in a small block of flats. Each drop pipe supplies three sets of fittings, each comprising bath, basin, and sink. The flow riser, overhead main, and drop pipes, as far as the last set of fittings, have their diameters determined by the flow required from the taps. These diameters are marked on the diagram. The problem then becomes one of calculating sizes for the return main and the drop pipes below the bottom branches to the fittings such that a circulation is maintained through all the drop pipes. The circulation should maintain water at all the fittings with a temperature not more than about 30° to 40° Fahr below that of the water in the cylinder.

Finding Heat Loss from the Pipes

The first step in design is to find the heat loss from the pipes. Each drop pipe, with its run-outs at the top, consists of 50 ft. of $1\frac{1}{4}$-in. pipe.

Referring to Table II, previously given (see page 91), the heat loss is 80 B.Th.U. per linear foot of $1\frac{1}{4}$-in. pipe. The total heat loss from each drop pipe is then $50 \times 80 = 4{,}000$ B.Th.U. per hour.

Pipe lengths AB and CD are each 20 ft. long, and the flow will give off $20 \times 90 = 1{,}800$ B.Th.U. per hour. Allowing the loss from the return as two-thirds that from the flow, these two sections lose 3,000 B.Th.U. per hour. The water to provide this must flow through drops 2 and 3, so that each must carry $4{,}000 + 1{,}500 = 5{,}500$ B.Th.U.

The main flow and return from the cylinder is 51 ft. long, and if $1\frac{1}{2}$-in. pipe throughout, gives off $57 \times 90 = 5{,}130$ B.Th.U. Allowing this load to be divided equally among the drop pipes, the following are the B.Th.U. for each. No. 1, $4{,}000 + 2{,}700 = 6{,}700$; Nos. 2 and 3, $5{,}500 + 2{,}700 = 8{,}200$.

Pipe sections AB and CD each carry water to and from drop pipes 2 and 3, and so their load is $8{,}200 \times 2 = 16{,}400$ B.Th.U. The main flow and return from the cylinder also carry the water for drop 1, and their load is $16{,}400 + 6{,}700 = 23{,}100$ B.Th.U. Assuming that the temperature falls 50° Fahr. between leaving the cylinder and returning to it, the pounds of water flowing can be tabulated as follows :—

Drop pipe No. 1	134 lb.
,, ,, No. 2	164 lb.
,, ,, No. 3	164 lb.
Pipes AB and CD	328 lb.
Main flow and return	462 lb.

Calculation of Temperature Drop

Now, as with the previous example, the temperature drop between the centre of the rising column and the centre of the falling column must be found. The centre of the rising column may be taken as 17 ft. from the top of the cylinder, so that from this point to point A is 27 ft. Referring to Table III on page 92, $1\frac{1}{2}$-in. pipe when carrying 462 lb. has a temperature drop of 0·2° Fahr. per foot. The total temperature fall to point A is $27 \times 0{\cdot}2° = 5{\cdot}4°$ Fahr.

Pipe section AB is 20 ft. long, $1\frac{1}{2}$-in. diameter, carrying 328 lb. The temperature drop per foot is 0·28° Fahr., the total in the section being $0{\cdot}28° \times 20 = 5{\cdot}6°$ Fahr. The total temperature fall to point B becomes $5{\cdot}4° + 5{\cdot}6° = 11°$ Fahr. From B to the centre of drop pipe 3 is 36 ft. The pipe diameter is $1\frac{1}{4}$ in., and it is carrying 164 lb., giving a temperature drop of 0·49° Fahr. per foot, and a total of $36 \times 0{\cdot}49° = 17{\cdot}6°$ Fahr. The temperature difference between the centre of the rising pipe and the centre of drop pipe 3 is thus $11° + 17{\cdot}6° = 28{\cdot}6°$ Fahr. This also applies to drop pipe 2. In a similar manner it can be calculated that the temperature fall to the centre of drop pipe 1 is 26·5° Fahrenheit.

It was stated in the previous section that it may be taken that water

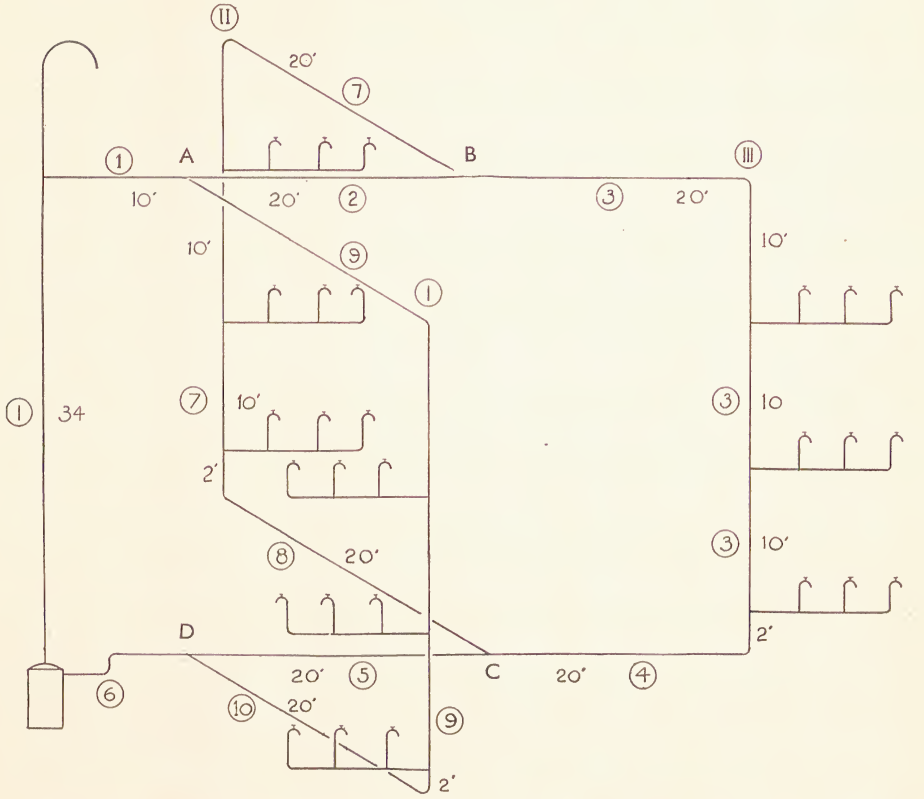


Fig. 1.—CALCULATION OF SECONDARY CIRCULATION OF DOWN-FEED SYSTEM

increases in density by 0·02 lb. per cubic foot for each degree fall in temperature. From this the circulating pressure becomes, for drop No. 1, $26·5 \times 0·02 = 0·53$, and for drop pipes 2 and 3, $28·6 \times 0·02 = 0·57$, lb. per square foot per foot height. The drop pipes are each 32 ft. high, so that the total circulating pressures become $0·57 \times 32 = 18·2$ lb., and $0·53 \times 32 = 17·0$ lb., per square foot respectively.

Determining Pipe Diameters to Absorb Pressure

Having arrived at the circulating pressure, it remains to determine the pipe diameters to absorb the pressure. Start this by numbering each pipe section, carrying a different weight of water, from the cylinder round the circuits and back, as shown in Fig. 1 by the ringed figures. Note that the pipe comprising each drop and its branches have two numbers, one applying to the length of pipe of which the diameter is known, and the second to the unknown diameter.

(1) *Pipe Section*	(2) *Lb.*	(3) *D*	(4) *L*	(5) *RF*	(6) L_1	(7) $L + L_1$	(8) *P*	(9) $P(L + L_1)$
1	462	$1\frac{1}{2}$	44	8	12	20	0·0072	0·144
2	328	$1\frac{1}{2}$	20	—	—	20	0·0035	0·07
3	164	$1\frac{1}{4}$	50	2	2·5	53	0·0031	0·164
4	164	$\frac{1}{2}$	22	2	1	23	0·35	8·05
5	328	$\frac{3}{4}$	20	—	—	20	0·2	4·0
6	462	$\frac{3}{4}$	13	4	3	16	0·275	4·4
								16·828
9	134	$1\frac{1}{4}$	50	4	5	55	0·002	0·11
10	134	$\frac{1}{2}$	22	4	2	24	0·2	4·8
								4·91

Fig. 2.—TYPICAL CALCULATION SHEET

The Calculation Sheet

It is wise in this type of calculation to adopt a calculation sheet, such as that shown in Fig. 2. It contains nine columns, the letters at the top of each having the following meanings and uses: Pipe section refers to the number of the pipe shown in Fig. 1. In the second column, the weight of water flowing in pounds per hour in each section is written. D, at the top of the third column, gives the diameter of each pipe section. In the fourth column is given the length L of each pipe section in feet. RF, at the top of the fifth column, indicates the total of the resistance factors taken from Table I on page 88. L_1 is the equivalent pipe length corresponding to the resistance factors. $L + L_1$ is the total length arrived at by adding L to L_1. P is the pressure drop per foot, taken from the chart previously given. Column 9 is obtained by multiplying columns 7 and 8, and gives the total pressure drop in each pipe section.

Deal First with the Longest Run and Lowest Circulating Pressure

Now the columns must be filled in as far as possible. The most unfavourable circuit, the one having the longest run and lowest circulating pressure, should be dealt with first. In the present instance it will be the circuit of either drop pipes 2 or 3. Taking the latter, the length of each pipe section and the weight of water flowing through it are entered on the calculation sheet. Starting at the cylinder, the first pipe section is 44 ft. long, and carries 462 lb. These particulars are written down, and so with all the pipe sections comprising the circuit back to the cylinder. At this time, too, the factors for the elbows, tees, etc., taken from Table I, page 88, may be shown on the sheet.

Next Calculate the Pressure Loss in Pipe Diameters

Now the pressure loss in the pipe diameters already determined should be calculated. This will include pipe sections 1, 2, and 3. The pipe diameters are written down, and also the equivalent length for the resistance factors, in column 6. Columns 4 and 6 are added together to give column 7. Referring to the chart, Fig. 6 on page 89, the pressure drops per foot of pipe are read off, and entered in column 8. Multiplying columns 7 and 8 together gives column 9, the total pressure drop in each pipe section. If this is done for the first three sections, it will be found, as in Fig. 2, that the total pressure loss in them is 0·378 lb. per square foot.

The circulating pressure for drop pipe 3 is 18·2 lb. per square foot. Subtracting 0·378, there remains for pipe sections 4 to 6, 17·84 lb. per square foot. The total length of these three sections is 55 ft. Adding 20 per cent. to allow for the effect of resistances, the equivalent total length is 66 ft. Dividing the available pressure, 17·82 lb. per square foot, by 66, the allowable pressure drop per foot is about 0·3 lb. per square foot. Again referring to Fig. 6 in the last article (page 89), it is found that $\frac{1}{2}$-in. pipe is necessary for section 4, and $\frac{3}{4}$-in. for sections 5 and 6, with this pressure drop. These diameters are entered on the calculation sheet.

Actual Pressure Drop per Foot

Next, the actual pressure drop per foot in these pipe sections must be found from the chart. Reference to this will show that $\frac{1}{2}$-in. pipe, carrying 164 lb., absorbs 0·35 ; $\frac{3}{4}$-in., carrying 328, absorbs 0·2 ; and $\frac{3}{4}$-in., carrying 462, absorbs 0·275, all in pounds per square foot per linear foot. The diameters being determined, L can be calculated, and then column 7 obtained. Multiplying columns 7 and 8, the total pressure drop in each pipe section is found and written in column 9.

When column 9 is added up it is found that the total pressure used in the complete circulation is 16·83 lb. per square foot. The available circulating pressure is 17·82 lb., giving a surplus of 0·99 lb. per square foot. This could be used up by reducing about 1 ft. of $\frac{3}{4}$-in. pipe to $\frac{1}{2}$ in. This is, however, unnecessary, so long as the remaining circuits are calculated to have about the same proportion of surplus circulating pressure.

Drop pipe No. 2 is constituted exactly as No. 3, and the same conditions will apply. Pipe section 8 must therefore be made $\frac{1}{2}$ in., as section 4. Drop pipe No. 1 requires separate consideration. The water flowing through it has also to flow through pipe sections 1 and 6. The pressure absorbed in these is, from Fig. 2, 4·54 lb. per square foot. The circulating pressure is 17 lb. per square foot, and there remains for pipe sections 9 and 10, $17{\cdot}0 - 4{\cdot}54 = 12{\cdot}46$ lb. per square foot.

The various particulars of sections 9 and 10 are entered on the calculation sheet as before. Section 10 is $1\frac{1}{4}$ in. in diameter, and it is found from the chart that the total pressure per foot is 0·002 lb. per square

foot, giving a total pressure loss of 0·11 lb. per square foot in the pipe section. There remains for pipe section 10 a pressure loss of 12·46 — 0·11 = 12·35 lb. per square foot. Allowing for the same surplus as drop No. 3, of about 1 lb. per square foot, the pressure drop per foot in section 10 must be 11 ÷ 26 = about 0·4 lb. per square foot. It is found from the chart that ½-in. pipe, carrying 134 lb., requires a pressure of 0·2 lb. per square foot per linear foot. This size and pressure drop are entered on the calculation sheet, and the calculation completed as shown in Fig. 2. When this is done it is seen that the total pressure absorbed in sections 9 and 10 is 4·91 lb. per square foot, against the 13·55 lb. per square foot. This shows a considerable excess, and a valve should be fixed in section 10. This valve may be closed as necessary to absorb the surplus pressure.

Towel Rail Calculations

This completes the calculation, and it is now certain that a satisfactory circulation will be obtained in all drop pipes. If towel rails are supplied from the drops, the design method will be the same, the heat loss from the rails being taken in with that of the drop pipe. The cooling effect of the rails can be obtained by dividing the heat loss from each rail by the pounds of water flowing down the drop. The average temperature of the drop must then be obtained by multiplying the length of each section by the temperature of the water in it and dividing by the total length. From this the average density of the water in the drop can be found, and hence the circulating pressure.

The calculations and results obtained should be examined and compared with the corresponding figures for the up-feed system outlined previously. It will be found that the down-feed system has a greater circulating pressure and requires smaller return pipes throughout. It often happens with an up-feed system that in order to obtain a satisfactory circulation the return pipes must be as large as the flow.

It is wise, where possible, with such a system, to calculate the return pipes to supply part of the water to the taps. The large size necessary will not then be uneconomic, but will enable the flow pipe to be reduced in size slightly. With a down-feed or drop system, however, the return pipes need not be large. In such a case they should not be relied upon to supply water to the taps. There is, of course, no reason why these pipes should not be determined to give a flow to the lower-floor taps. The only disadvantage is that the system will circulate much more quickly. This is evident from Fig. 2, where practically the whole resistance is concentrated in the return. This quick circulation means a higher temperature maintained in the pipes, with a consequent greater heat loss. This will result at best in a waste of fuel, and in the summer the extra heat may be a nuisance. A hot-water supply system is, of course, in use throughout the year.

Determining Suitable Diameters for Secondary Flow Pipes

The determination of suitable diameters for the secondary flow pipes, which supply the water to the taps, is a comparatively simple matter if the calculation of circulations has been thoroughly understood. The same principles apply. A given head or pressure is available to force the water along the pipe lines and out of the taps. This will vary with the depth below the cold-water tank at which the tap is situated. When the required quantities of water are flowing along the pipes, the pressure absorbed in friction must equal the pressure available.

Rate of Outflow from Pipes

The rate of outflow desirable from any tap will vary with the type and class of building. Suitable figures for normal installations are: baths, 6 gal. per minute; sinks, 4 gal. per minute; and lavatory basins, 2 gal. per minute.

If there is any likelihood of all the taps being turned on at once, the quantity of water flowing through the mains and branches is simply arrived at by adding up the number of taps served by them and multiplying by the desired outflow from each. Usually this will not apply. An assumption must be made as to the number of taps likely to be in use at the same time. If this is not done the apparatus will be unduly expensive, and there will be a big loss of heat owing to the unnecessarily large mains.

If a bathroom contains other fittings in addition to a bath, it is only necessary to allow for the bath when calculating riser and main sizes. Generally, when risers or drop pipes supply a number of floors, it may be taken that the required flow will be 60 per cent. of the total of the flow from all fittings. Where a main supplies two risers it should be calculated for a flow of 90 per cent. of the total of the two risers. For three risers take 80 per cent., four risers 70 per cent., and so on down to 40 per cent., which should be the minimum. Further information is given in Tables I and II of this section.

TABLE I

FLOW REQUIRED FOR NUMBERS OF FITTINGS IN GALLONS PER MINUTE

Type of Fitting	*Number of Fittings*					
	1	2	5	10	20	40
Lavatory Basins ..	2	4	7	12	22	35
Baths	6	12	30	22	48	90
Sinks	4	8	15	25	45	70
Showers	6	12	22	50	90	150

TABLE II

BLOCKS OF FLATS—FLOW REQUIRED FOR RISERS AND DROP PIPES IN GALLONS PER MINUTE

Floor	*Flat with 1 Bath*	*Flat with 2 Baths*	*Flat with 3 Baths*
Top Floor	6	8	11
Next Floor	11	15	20
Next Floor	15	22	29
Next Floor	20	27	35
Next Floor	24	32	42
Next Floor	27	36	46
Next Floor	29	39	51
Next Floor	31	41	53
Next Floor	32	43	55

An Example

The method of dealing with the calculation will be best illustrated by an example. Fig. 3 is the diagrammatic representation of the hot-water supply installation for a small block of flats. It consists of four identical risers, all supplying a flat on each of four floors. Each flat contains a bath, basin, and sink. Referring to Table II, the piping to the top floor must supply 6 gal. per minute, to the next floor 11 gal. per minute, to the next 15 gal. per minute, and the piping connecting to the main must supply 20 gal. per minute. This will apply to all risers.

Pipe section 3, supplying risers 3 and 4, must carry $20 \times 2 \times 0{\cdot}9 = 36$ gal. per minute. Section 2, serving three risers, must supply $20 \times 3 \times 0{\cdot}8 = 48$ gal. per minute, and section No. 1, $20 \times 4 \times 0{\cdot}7 = 56$ gal. per minute. It will be seen how allowance is made for the likely number of taps to be in use at once. If all were turned on, the load would be $16 \times 12 = 192$ gal. per minute, but the main is to be sized for 56 gal. per minute. It must be remembered that this quantity of water also flows through the cold-water supply pipe. The friction loss in this must be taken into account.

Consider the Most Unfavourably Placed Tap First

Here again, the first tap to be considered is the most unfavourable one. If any other is considered first it is extremely probable that when the most unfavourable tap is dealt with the pipes already determined will be too small. The first tap, then, to be calculated must be the one on the farthest riser on the top floor, as here the water has the longest travel and the least head available to overcome the friction.

The total distance the water has to flow to the farthest tap is, from Fig. 3, 155 ft. from the cylinder. The water reaches the tap by cold water from the tank displacing the hot water in the cylinder. The length of the cold-feed pipe, 80 ft., must therefore be added to the 155 ft.

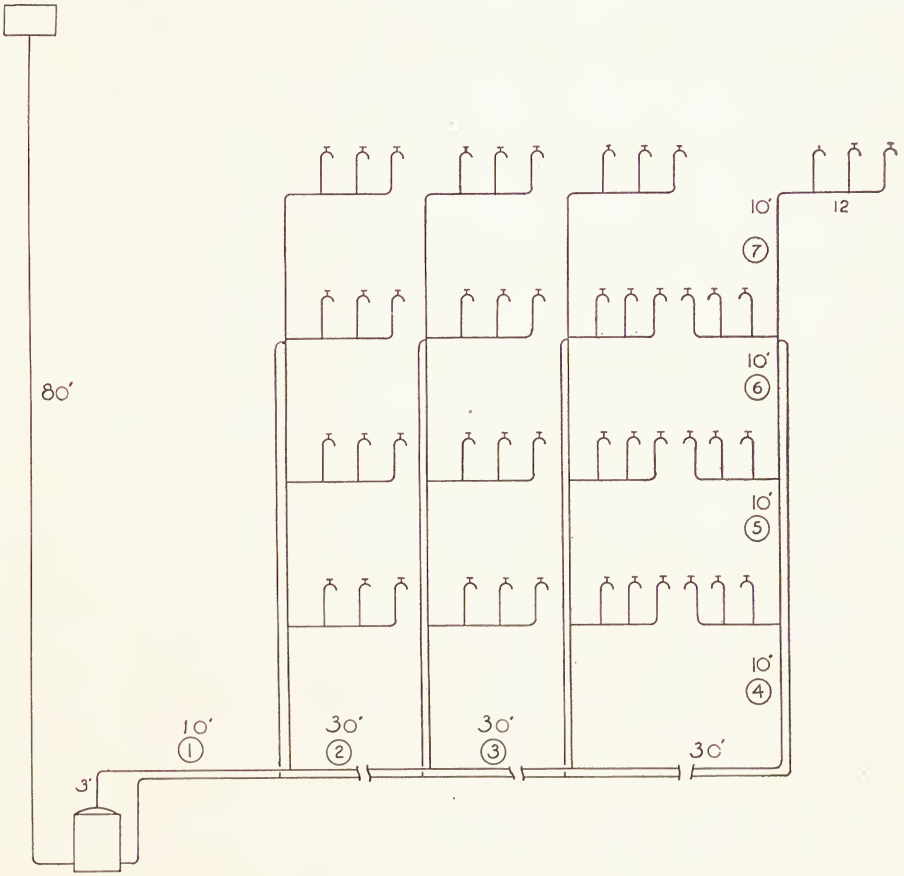


Fig. 3.—CALCULATION OF SECONDARY FLOW OF TYPICAL UP-FEED INSTALLATION

of the secondary flow, making a total length of 235 ft. As with a circulation, allowance must be made for the effect of resistances. The diameter being unknown, an approximation must be made. An appropriate allowance will be 50 per cent., making the equivalent length of the secondary flow pipe 235 ft. by 1·5, which is about 350 ft.

Pressure and Pressure Drop in Pipes

The water level in the tank is 10 ft. above the highest tap, and this corresponds to the pressure available to force the water along the pipes and out of the taps. The pressure drop per foot will be 10 ÷ 350, which is approximately 0·03 ft. Referring to Table III, it is found that a $2\frac{1}{2}$-in. pipe will carry 46 gal. per minute, with a pressure drop of 0·03 ft. per linear foot. This size may be adopted for the cold-feed pipe and pipe

sections 1, 2, and 3. With the same pressure drop, pipe section 4 will need to be 2 in.; sections 5 and 6 can be 1½ in., and section 7, 1¼ in. The connections to the bath should be 1 in., to the sink 1 in. or ¾ in., and to the basin ¾ in. The actual equivalent length of the resistances of the elbows should now be computed from the Tables previously given. If widely different from the 50 per cent. of 350 ft. allowed, the calculation should be made again, using the correct length.

TABLE III

PRESSURE LOSS IN PIPES

Pressure Loss in Feet per Linear Foot	*Discharge in Gallons per Minute*								
	½ *in.*	¾ *in.*	1 *in.*	1¼ *in.*	1½ *in.*	2 *in.*	2½ *in.*	3 *in.*	4 *in.*
0·01	0·48	1·3	2·7	4·7	7·4	15·0	27·0	42·0	86·0
0·015	0·59	1·72	3·41	5·97	9·35	19·0	33·1	53·0	105·0
0·02	0·675	1·86	3·82	6·68	10·5	21·6	37·7	59·5	121·0
0·025	0·75	2·08	4·25	7·5	11·75	24·0	42·0	66·5	135·0
0·03	0·83	2·28	4·7	8·19	12·96	26·6	46·7	73·2	150·5
0·04	0·961	2·64	5·4	9·46	14·99	30·4	53·2	84·3	172·5
0·05	1·07	2·95	6·05	10·5	16·7	34·1	59·7	94·0	194·0
0·06	1·18	3·24	6·64	11·58	18·28	37·04	65·4	103·4	213·8
0·08	1·38	3·96	8·0	13·62	21·5	44·1	77·0	122·0	249·0
0·1	1·5	4·16	8·5	15·0	23·5	48·0	84·0	133·0	270·0
0·15	1·87	5·18	10·08	18·5	29·4	60·1	104·3	165·5	337·6
0·2	2·14	5·9	12·0	21·2	33·0	68·3	118·0	188·0	385·0
0·4	3·02	8·3	17·1	29·8	47·0	96·6	168·6	256·0	546·0
0·6	3·77	10·4	21·38	37·4	58·8	120·7	211·0	332·0	680·0
0·8	4·35	12·0	24·6	43·2	68·0	139·4	243·0	384·0	790·0
1·0	4·77	13·1	27·0	47·0	74·0	152·7	268·0	420·0	860·0

There are two points which require consideration in the above. Firstly, the gallons carried by the pipes chosen from Table III are not exactly according to Fig. 2. This is immaterial, as gallons per minute shown in Fig. 2 are only an approximation. The pipe diameters giving a carrying capacity nearest to that required should be chosen.

The second point is that no water has been considered as flowing through the secondary return. Obviously this will happen, and it may be found when calculating the circulation that quite a large secondary return is required. In such a case it is best to allow the secondary return to supply, say, the top two floors, its size being determined accordingly. The secondary flow would then supply the lower floors. The aim should be to make the diameters as nearly as possible equal.

Next the Supply Pipes Nearer the Cylinder

When the index tap has been considered, the supply pipes nearer the cylinder must be calculated. Taking riser 1, the total length from

the cold-water tank to where riser 1 joins the main is 93 ft. These pipes have been sized for a pressure drop of 0·03 ft. per foot. The head used in 93 ft. is $93 \times 0{\cdot}03 = 2{\cdot}8$ ft., and adding 50 per cent. for the effect of elbows, etc., this becomes 4·2 ft.

The length of travel for the top tap on riser 1 is 52 ft. from the main. Allowing for fittings, this amounts to $52 \times 1{\cdot}5 = 78$ ft., or, say, 80 ft. The allowable pressure drop per foot is $(10 - 4{\cdot}2) \div 80 = 0{\cdot}073$ ft. Referring to Table III, the requisite sizes can be chosen as with riser 4.

Sizes of Pipe Branches

The diameter for branches on the lower floors can be taken from Table IV with sufficient accuracy. This Table is made up for 10-ft. floor heights, but by interpolation it may be used for other floor heights. The Table is in two parts, one for branches supplying fittings up to 15 ft. from the riser or drop pipe, and the second part for branches longer than 15 ft.

TABLE IV

CAPACITY OF BRANCHES FROM RISERS OR DROP PIPES IN GALLONS PER MINUTE

Floor below Top Floor	*Branches less than 15 ft.*			*Branches more than 15 ft.*		
	½ *in.*	¾ *in.*	1 *in.*	½ *in.*	¾ *in.*	1 *in.*
1	2½	7	16	2	5	11
2	4	10	22	2½	6	15
3	5	12	27	3½	8	18
4	6	14	32	4	9	21
5	6½	16	35	4	11	23
6	7	18	38	4½	12	25
7	7½	19	42	5	13	28

In the present case, none of the branches supply fittings more than 15 ft. from the risers, so that the first half of the Table will apply. Each branch must supply 6 gal. per minute, and, referring to the Table, the branch on the top floor but one must be ¾ in. The connection to the bath will have the same diameter, that to the sink (4 g.p.m.) must be ¾ in., and to the basin (2 g.p.m.) ½ in.

How to Avoid Large and Uneconomical Pipe Sizes

It will sometimes happen with long pipe-runs to the farthest tap, and with small difference in level between this tap and the cold-water tank, that very large and uneconomical pipe sizes are required. It must be realised that apart from the initial outlay, long runs of large-diameter

pipe involve increased running costs. It may be found that more fuel must be burnt to keep the pipes warm than is required to heat the water actually used. This is usually complete waste, as the warm pipes do no good.

Employing the Cylinder-tank System

There are two methods of overcoming the difficulty. The first makes use of a cylinder-tank system, and the second, a pump. The cylinder-tank system may be applied to either an up-feed or a down-feed installation. An application to the former is given in Fig. 4. The difficulty with an up-feed system is that one tank will assist only one riser. In Fig. 4 one riser is higher than the others, and a tank applied to this will serve a very useful purpose. Without the tank, the whole of the mains would be governed in size by these taps on the top floor. With the tank, the mains may be calculated to supply the taps on the floor below. This will double the pressure available, and probably enable all the mains to be reduced in size.

The piping between the tank and the top-floor taps should be calculated for these taps alone. This is done exactly as before, by making the pipes of such sizes that the friction in them, when the required flow takes place, is equal to the height of the tank above the taps. The piping between the top-floor taps and those on the floor below theoretically supply no water. Their diameters should be determined by the circulating requirements. When calculating the circulation, the pipes must be large enough to supply the heat loss from the tank and also to heat the water in it in two to three hours.

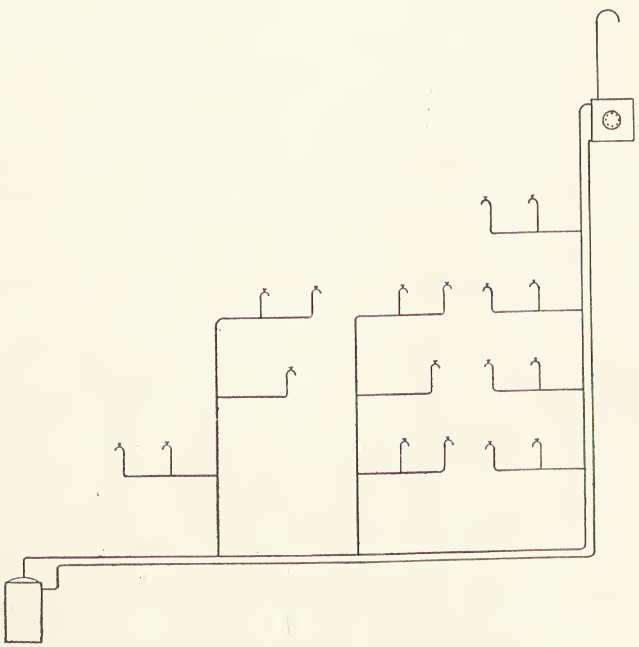


Fig. 4.—UP-FEED CYLINDER-TANK SYSTEM

It has been assumed in the above that the whole of the water for the top floor is drawn from the

tank. There is no necessity for this, and the pipes can be calculated to supply some water from the tank and some from the cylinder via the risers. The capacity of the tank should be varied accordingly, but with an ample margin. It is essential that a vent be taken from the tank, as shown, otherwise it will never be filled. It is also wise, except under special circumstances, to lag it. Although the deposition of scale is likely to be small, it is good practice to fit the tank with a manhole.

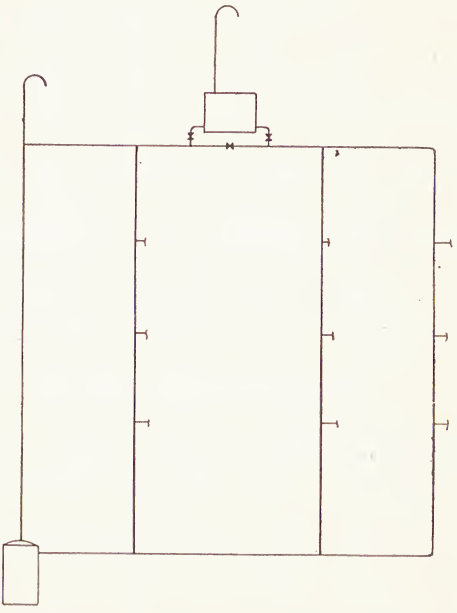


Fig. 5.—DOWN-FEED CYLINDER-TANK SYSTEM

With a normal type of down-feed apparatus, it is impossible to isolate the effect of an overhead tank and confine it to one drop pipe. It will be seen from Fig. 5 that the tank must be connected to the overhead main and so supply all the drop pipes. This arrangement has the same advantages as with the up-feed system, the main one being that an adequate supply can be assured from the top taps without extremely large mains. The best method of making connections is illustrated. Flow and return connections are taken from the overhead main, and join the tank near the bottom. Valves are fitted to these connections, so that the tank may be isolated, if necessary. A valve in the by-pass connection enables the flow through the tank to be adjusted, although this is not strictly necessary.

Using a Centrifugal Pump to Avoid Large Mains

The alternative method of avoiding large mains, when long runs are necessary to taps and little head is available, is to use a centrifugal pump. It will be realised that if a pump is arranged so that its suction is connected to a cylinder and its delivery to a pipe leading to a tap, the pressure created by the pump will be available to force water along the pipe and out of the tap. If the cylinder itself is under pressure from some external source, the total pressure forcing the water through the piping system and out of the taps is that due to the external source plus that due to the pump.

If, for example, a tap is 10 ft. below the cold-water tank level, and a pump is employed giving a head of 10 ft. (quite a low head for a pump),

the available pressure is doubled. The pump must be capable of delivering sufficient water to supply all the taps likely to be in use at once. This is essential, as is a motor having a rated horse-power well above the maximum required by the pump. Care should also be taken that the pump is chosen on the right part of its characteristic curve, so that if the head against which the pump actually works is less than that theoretically determined, overloading will not take place. The makers will give advice concerning this. These points must be attended to, or else it will be found that the overload release on the motor starter trips whenever a number of taps is turned on.

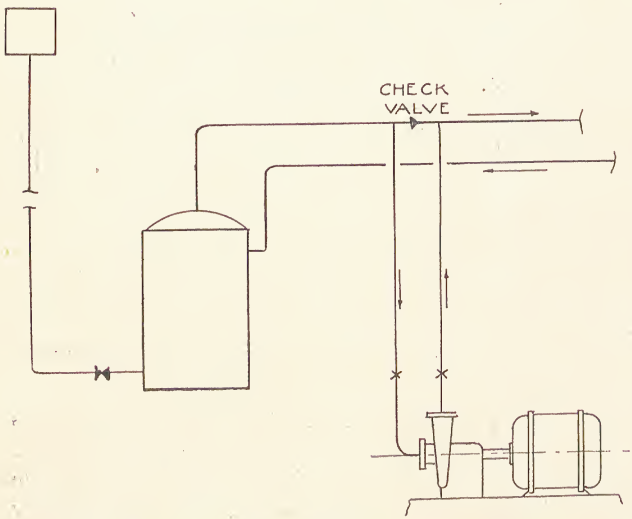


Fig. 6.—CENTRIFUGAL PUMP TO INCREASE PRESSURE AT TAP

Method of Connecting Pump to Piping

The best method of connecting the pump to the piping is given in Fig. 6. The suction and delivery are joined to the secondary flow on either side of a check-valve. The suction is on the cylinder side of the check. In this way the cylinder is not subject to the pressure from the pump. The check-valve prevents the water flowing from the main into the pump, and back again in the opposite direction from the arrow. At the same time, when a tap is opened the check does not prevent the static head of the cold-water tank assisting the pump to deliver water to the tap. The valves shown on the suction and delivery connections enable the pump to be isolated for repairs. Pumps, motors, isolating and check-valves may be obtained as a complete unit. These will be considered in a later section.

It will, of course, be realised that with a pump used as above to give a good delivery to the taps, the pressure created is also available to maintain the secondary circulations. The pressure created will be comparatively so great that the circulating pressure due to the cooling of the water may be completely ignored. If a pump head is given in feet, it may be converted to pounds per square foot, for use with the chart previously given, by multiplying by the average density of the water in the installation. This may be taken for normal use as 61·5 lb. per

cubic foot. A pump head of 10 ft., therefore, is equal to a pressure of 615 lb. per square foot.

It will be found, in such cases, that very small secondary circulation pipes are required. Long, horizontal runs of ½-in. diameter piping should, however, be avoided, particularly if inaccessible. They are extremely liable to stoppage, particularly in a hot-water supply installation, where probably scale will be formed. It is better to use a larger pipe and regulate the flow with a valve. If this becomes blocked, the scale will be easily removed, because the valve should be accessible.

QUESTIONS AND ANSWERS

What special consideration should be borne in mind when designing Secondary Circulations ?

The cooler water in any particular circuit creates the circulating pressure and this pressure must be absorbed in friction. In other words, the resistance to the flow of water must be balanced by the circulating pressure to quite close margins when dealing with complex networks of piping.

What is the Heat Loss from 49 ft. of 2½-in. pipe ?

The heat loss from 1 linear ft. of bare 2½-in. pipe is 125 B.Th.U. per hour (see Table II, page 91). Therefore, the loss from 49 ft. of pipe is $125 \times 49 = 6{,}125$ B.Th.U. per hour.

Assuming that the temperature falls 50° F. between leaving the cylinder and returning, how much water will flow through a pipe series at a Heat Loss of 36,000 B.Th.U. per hour ?

The weight of the water flowing is $36{,}000 \div 50 = 720$ lb. per hour.

How may the Temperature Drop be calculated in a system ?

The temperature drop is found by considering the distance between the centre of the rising column and the centre of the falling column, the drop in each section between these two points being calculated in relation to its size and weight of water flowing per hour. This may be done by referring to the Table showing the temperature drop in pipes in ° Fahr. per foot of bare pipe (see Table III, page 92). The various temperature falls between these points can then be totalled.

How much does water increase in Density with the Fall in its Temperature ?

By 0·02 lb. per cubic foot for each degree fall in temperature.

If the temperature fall is 28·5° F., what will the Circulating Pressure be ?

$28{\cdot}5 \times 0{\cdot}02 = 0{\cdot}57$ lb. per square foot per foot height.

What is the Total Circulating Pressure in a drop pipe 32 ft. high, with a temperature fall of 28·5° F. ?

$28{\cdot}5 \times 0{\cdot}02 \times 32 = 18{\cdot}2$ lb. per square foot.

What are the desirable Rates of Outflow from Taps ?

The rate of outflow desirable from any tap will vary with the type and class of building. Suitable figures for normal installations are :—

Baths, 6 gal. per minute.
Sinks, 4 gal. per minute.
Lavatory basins, 2 gal. per minute.

If there is a likelihood of all taps being turned on at once—for example, with wash basins in a factory or workshop—on what basis is the Quantity of Water Flowing through the mains and branches arrived at ?

By adding up the number of taps served by the mains and branches and multiplying by the desired outflow from each.

What Quantity of Water should be allowed for to supply a Bathroom containing other fittings in addition to the bath ?

It is only necessary to allow for the bath outflow when calculating riser and main sizes.

What will be the required Flow when risers or drop pipes supply a number of floors ?

It may be taken that the required flow will be 60 per cent. of the total of the flow from all the fittings.

How much Flow should be allowed for when a main supplies two, three, four, and seven risers ?

A flow of 90 per cent. of the total of two risers should be taken ; three risers, 80 per cent ; four risers, 70 per cent. ; and seven risers, 40 per cent.

What is the Flow required for two baths, one sink, and five lavatory basins supplied by one hot-water system in a house ?

Two baths will need a flow of 12 gal. per minute, one sink 4 gal., and five lavatory basins 7 gal. per minute.

SANITARY SURVEYING

PART III—SANITARY FITMENTS

UNDER this heading are included closets, baths, lavatory basins, bidets, and sinks. It will be well to consider the virtues of each in turn, together with the demerits of various forms of fitments found, particularly in old buildings.

Closets—Principle

Although one may be called upon to inspect a number of closets which are of an obsolete pattern, and are now prohibited by the sanitary authority's by-laws from being fixed, it does not necessarily follow that they should be condemned, unless one can prove that the particular fitment is in an insanitary condition, i.e. that a nuisance is in evidence which is likely to be injurious or dangerous to the health of the occupants. If the latter condition is in evidence, then the fitment must be condemned.

The guiding principle is that the closet, together with the flushing apparatus, should be such that the closet is self-cleansed, i.e. excreta should not foul the sides of the closet, the contents of the pan should be flushed into the soil pipe or drain, and the water in the trap should be entirely changed, while the surface of the closet has been thoroughly cleansed.

Prohibited Closets

Failure to comply with these requirements is usually found in the " prohibited " type of closet, such as the " pan and container " (Fig. 1), the " plug " closet (Fig. 2), the " wash out " (Fig. 3), the " long hopper " (Fig. 4) ; in addition, some of these closets have a concealed outgo, the joint to which is usually made of red lead and putty and is often found defective. These may be discovered in old houses, and they are invariably encased in wood, which is conducive partly to retain the foul odours arising from the defective joint.

Syphonic Closet

With the modern forms of closet these conditions do not arise, and the syphonic type is one which complies with the essentials of a good closet (Fig. 5). Although it has the appearance of a wash-down closet, the principle of action is quite different. It relies upon syphonic action

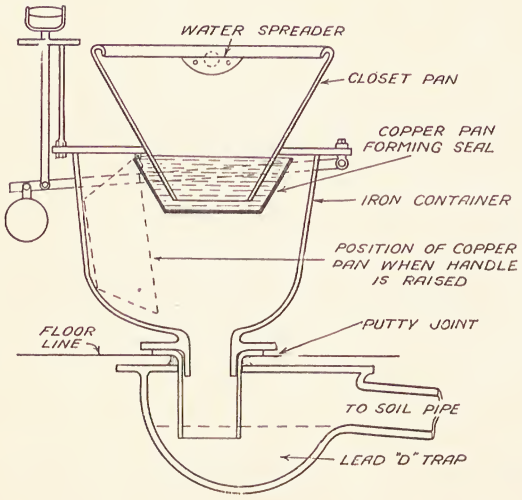


Fig. 1.—"PAN AND CONTAINER" CLOSET—NOW OBSOLETE

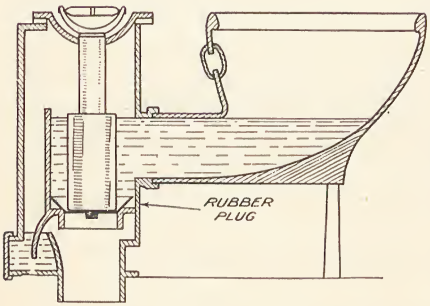


Fig. 2.—PLUG CLOSET—NOW OBSOLETE

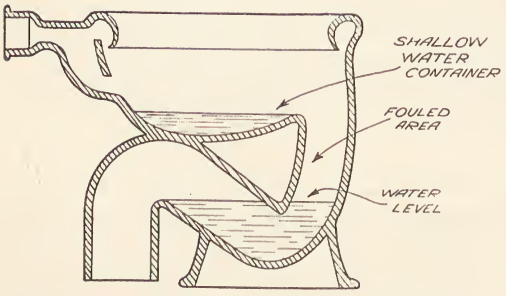


Fig 3.—THE OBSOLETE "WASH-OUT" CLOSET

brought about by reducing the air pressure on the outgo side of the trap, thus forming a partial vacuum, which enables the normal atmospheric air-pressure (14·7 lb. on the square inch) to force the contents of the closet into the soil pipe.

The subsequent flushing of water washes the inside of the pan, and a quantity of water temporarily held back provides for the sealing of the trap after syphonage has ceased. The water area, being much larger than that provided for the ordinary "wash-down" closet, renders it more proof against surface fouling; this water area is governed by the depth of the trap seal, which varies according to the type used. There is a number of syphonic closets on the market, and in each type the outgo joint is accessible.

Wash-down Closet

The popular "wash-down" pedestal (Fig. 6) has a number of features for commendation. It is simple in form, has no mechanical parts, is not enclosed, can be efficiently flushed by means of 2 gal. of water (Water Board regulation), while the outgo joint is above the floor and accessible. There is a number of makes on the market, and they differ somewhat in form, the best being those which do not permit the sides to be fouled. A large

water area, with not less than a 2-in. water seal, is a good feature. The direct discharge of water from the flushing cistern removes the contents of the closet and cleanses its sides.

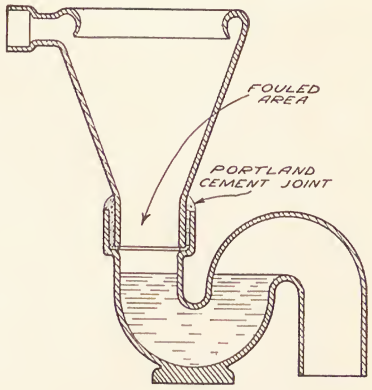


Fig. 4.—ANOTHER OBSOLETE CLOSET —THE "LONG HOPPER"

Baths

In old houses one finds the cased-in bath with a detachable wooden top, and sometimes a lead tray beneath the bath to catch the water which finds its way under the wooden top. The waste pipe, from the centre of the bottom, leads to a box trap with a concealed standing overflow, which acts as a plug to the trap and is actuated by a lever or pull-up knob.

This type of bath waste is considered insanitary, seeing that the waste pipe leading to the trap, some 18 in. to 2 ft. away, is not only subjected to fouling from the soapy bath-water, but receives the last drainings from the previous bather's water, which, if not rinsed away, comes back into the bath when next used. The possibility of foul odours pervading the apartment, due to decomposing soap from the lead tray and standing overflow, is very apparent.

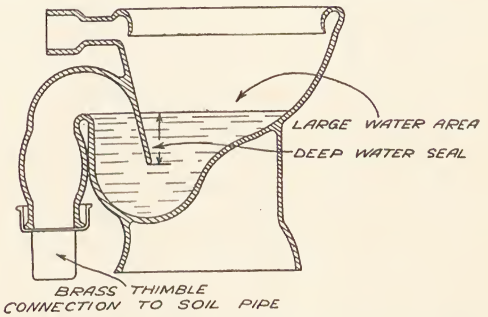


Fig. 5.—"SYPHONIC" CLOSET—WITH ONE TRAP

The Overflow Pipe

One frequently finds that the overflow pipe from the ordinary porcelain-enamelled iron bath is taken into the waste pipe on the stack side of the trap, thus nullifying the use of the trap (Fig. 7). This condition does, of course, constitute a nuisance, and the overflow should be made to discharge into the open air. The overflow pipe

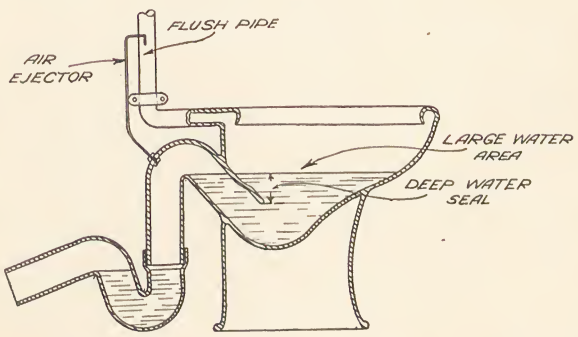


Fig. 5A.—"SYPHONIC" CLOSET—WITH TWO TRAPS

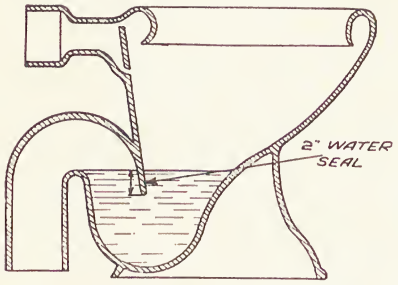


Fig. 6.—"WASH-DOWN" PEDESTAL CLOSET

is a necessary evil, seeing that it becomes fouled by the soap suds which form on the top of the bath water.

If it discharges into the open air, it is sometimes objectionable, as it is subjected to constant overflowing by some bathers; and, in addition, fouls the ground on which it falls.

If constructed as a standard overflow, odours from putrefying soap arise. Possibly the best method of dealing with the problem is to connect it to the bottom side of the trap, which minimises the area fouled and obviates fouling the ground. The water authorities, who require the overflow pipe to be a warning pipe and to be within view, frequently give concessions in the case of town flats, by allowing the overflow to be connected to the bath trap.

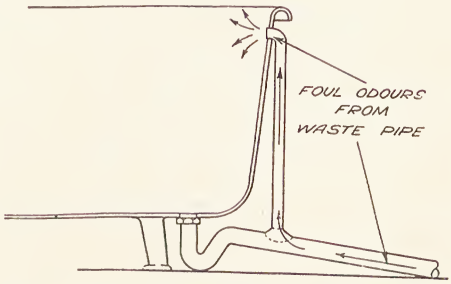


Fig. 7.—BATH OVERFLOW CONNECTED TO WRONG SIDE OF TRAP

Lavatory Basins

The main point to be observed in connection with this fitment is the overflow. The older type was made with the overflow to discharge into a $\frac{3}{4}$-in. diameter lead pipe, which was connected to the inlet side of the trap by means of a plumber's wiped joint, the top end of the pipe being enlarged and the joint made with red-lead putty. Very frequently this pipe became choked with deposits of soap, which passed through the slots or holes forming the overflow, no provision being made for cleaning-out purposes (Fig. 8).

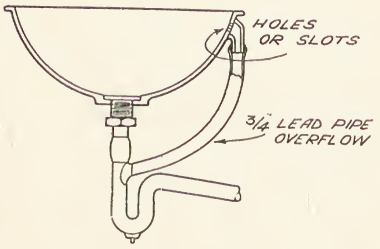


Fig. 8.—BAD FORM OF OVERFLOW FOR A LAVATORY BASIN

The modern basin is constructed with the overflow as an integral part of the fitting, and may be provided with slots or open weirs (according to choice), which allow for the cleansing of the overflow channel.

The brass waste and washer, which forms the connection between the basin and trap, is provided with a slot for the purpose of allowing the overflow water to pass into the trap. In the

writer's experience, many plumbers do not take sufficient care to adjust the slot opposite the overflow, and he has frequently found that, even if it has been properly adjusted, red-lead putty fills the aperture, thus nullifying the overflow provision and, in addition, giving rise to foul odours from the filth which accumulates within the overflow.

Where a ventilation pipe is required, in order to maintain the seal of the trap to a washing fitment, one frequently finds it installed on the crown of the trap, which is quite contrary to the purpose for which it is required. It is strictly an air pipe, and should not receive water discharges, which is more than probable in such a position, as water will tend to find its own level when the plug of the basin is released. The position required by the by-laws is "not nearer than 3 in. or more than 12 in. from the crown of the trap," and to be installed in the direction of the flow (Fig. 9).

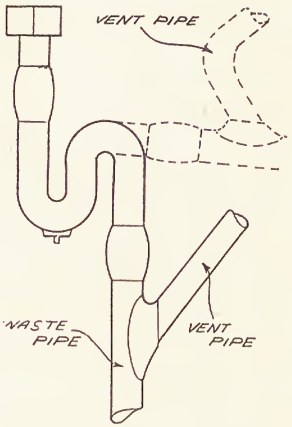


Fig. 9.—POSITION OF VENT PIPE IN RELATION TO TRAP OF A LAVATORY BASIN

Dotted lines show correct position for the vent to a P-trap.

Bidets

This washing fitment is not very well known, and rarely found in old houses, although of recent years it has been installed in a number of high-class flats and private suites in hotels (Fig. 10). It is fitted with a flushing rim, supplied with hot and cold water, and usually has a spray in the centre, which is actuated by control valves. The overflow is of the standard overflow pattern and discharges into the trap. This last provision is the one objection raised against this fitment; the overflow should be connected to the bottom of the trap, as previously described for baths.

Sinks

There are several types of sinks found in old houses, viz. lead-lined, glazed stoneware, teak, and York stone sinks. The lead-lined sink is used in the butler's pantry for silver, plate, and glass. The lead lining is usually found in a distorted and fractured condition due to hot water causing expansion of the lead. The

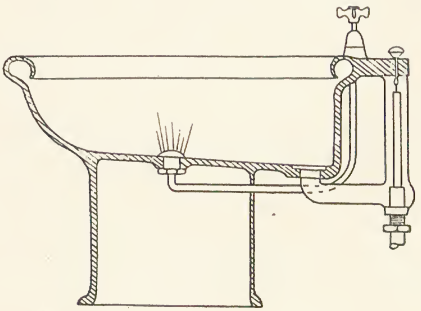


Fig. 10.—A BIDET

modern sink which has taken its place is the "Staybrite" steel sink, for which it is claimed that china will not break when dropped into it. Teak sinks are used for vegetable washing, and fitted with a standing waste in the corner of the sink, with a perforated shield around it. The glazed stoneware sink is a general-utility sink for kitchen or scullery use, and has now taken the place of the old York stone sink, which required constant scrubbing to keep it clean.

Such fitments as defective lead-lined sinks, badly chipped stoneware sinks, and York stone sinks should be specially noted in the report when making the survey.

QUESTIONS AND ANSWERS

When should Water-closets of obsolete pattern be condemned ?

When one can prove that the particular fitment is in an insanitary condition, i.e. that a nuisance is in evidence that is likely to be injurious or dangerous to the health of the occupants. The closet should be really self-cleansing, and the water in the trap should be entirely changed on flushing.

In what cases of Closets now Prohibited is failure to comply with requirements usually found ?

In pan-and-container, plug, wash-out, and long-hopper closets.

What is the principle of action of the Syphonic Closet ?

Syphonic action is brought about by reducing the air pressure on the outgo side of the trap, thus forming a partial vacuum that enables the normal atmospheric air pressure to force the contents of the closet into the soil pipe. The subsequent flushing of water washes the inside of the pan, and a quantity of water temporarily held back provides for the sealing of the trap after syphonage has ceased.

What is a frequent Faulty Connection of the Overflow Pipe found with Porcelain-enamelled Iron Baths ?

The overflow pipe is frequently found to be taken into the waste pipe on the stack side of the trap, thus nullifying the use of the trap.

Where should the Overflow Pipe discharge to ?

Into the open air. Sometimes, in the case of town flats, the water authorities allow the overflow to be connected to the bath trap.

What is the Objection to Overflow of Lavatory Basin being connected by pipe to the Inlet Side of Trap ?

Very frequently this pipe becomes choked with deposits of soap, and there is usually no means for cleaning out.

HEATING AND VENTILATION

PART IV.—PANEL HEATING AND BOILERS FOR CENTRAL HEATING

THE term " panel heating " is used to describe either a system in which panels of pipe coils are embedded in plaster or that in which surface or plate panels are used.

The plaster-embedded panel consists of an arrangement of pipes of $\frac{1}{2}$-in. diameter or $\frac{3}{4}$-in. diameter, which, after being placed in position against either a wall or ceiling, is plastered over. The plastering is, of course, over the whole area of the wall or ceiling, and on completion there is no visible evidence of any form of central heating.

The Panel Coils

The panels are usually made up by bending the pipes as shown in Fig. 1. This type of panel is used only in forced circulation systems, where the pump creates sufficient head to overcome the resistance in the coils of continuous pipe forming the panel.

In the system where circulation must be by gravity, a grid pattern is used in order to reduce the resistance to the flow of water through it.

The difference in the length of travel can be easily noted by comparing Fig. 2 with Fig. 1. It is obvious that the resistance of the grid pattern is much less than in what is sometimes called the " hairpin " type. The cost of the grid panel is greater than the hairpin pattern, because of the number of welded joints needed in its construction. It is used only in small gravity installations and when fixed in a vertical position.

Where the pipes forming a panel run in a vertical direction, the grid pattern must be used, otherwise it would be difficult to clear the air from the system.

Water Temperatures Employed in Panel System

The use of a pump allows the system to be designed for a low temperature drop, and the pipes serving the panels can be kept to comparatively small diameters. The maximum temperature drop usually allowed for in sizing the circuits is 20° F., and the mean temperature should be maintained at a level not above 110° F. Higher temperatures cause excessive expansion, and the resulting tendency of the plaster covering to crack is difficult to avoid.

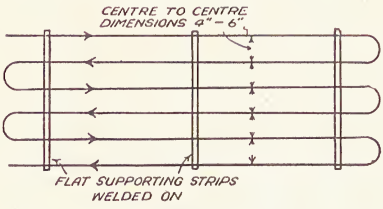


Fig. 1.—HAIRPIN TYPE OF EMBEDDED PANEL

The Plate-type Panel

In the plate-type panel, the waterways are distributed at the back and are approximately 1-in. diameter. It is by the process of conduction that the whole area of the panel is heated. This type of panel is usually made up by assembling a number of sections, the number varying, of course, with the size of panel required. It is not necessary to keep the temperature of the water below the temperature usually allowed for the ordinary radiator system, as the surface temperature of the panel will be lower by reason of the dissipation of the heat from the waterways over the large area which is not in contact with the water.

Fig. 2.—GRID TYPE OF EMBEDDED PANEL

Note that there is less resistance to the flow of the hot water through the piping, compared with Fig. 1.

It is advisable to fit insulating material, either of cork, asbestos, or glass silk, etc., behind all panels, especially those fixed against outside walls or top-floor ceilings. The proper insulation of the panels at the back will increase the heating effect and reduce fuel costs.

Arrangement of Pipe Circuits

The arrangement of the pipe circuits should be designed to avoid the possibility of air locks one of the most common faults in hot-water heating systems—and for this reason an up-feed system may be considered the most satisfactory.

Fig. 3 shows a typical arrangement, and the attention of the reader is directed to the method of connecting the panels to the mains.

It will be noted that the branches for the return connections are made above the level of the panels, and that the flow pipe is carried down to a control valve fixed at

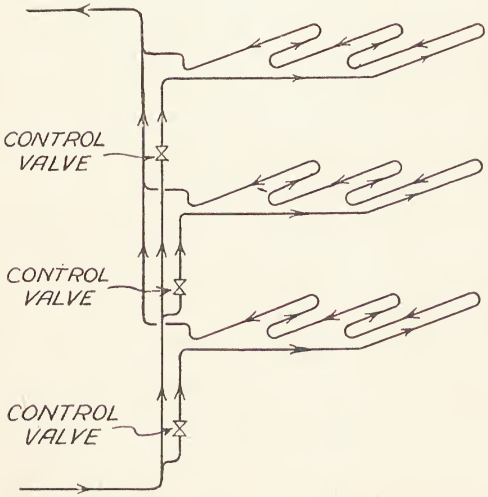
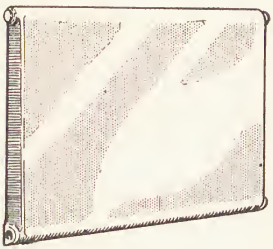
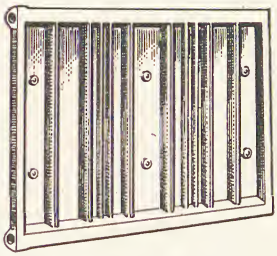


Fig. 3.—A TYPICAL ARRANGEMENT OF PIPE CIRCUIT FOR EMBEDDED PANEL WARMING

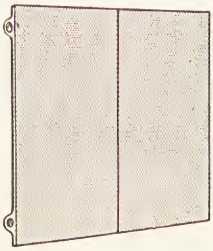
hand level, before the connection is made to the rising main. As the circulation is maintained by pump, the natural tendency for the water to flow in a downward direction is overcome, and any accumulation of air in the system is carried upward with the flow of water to the highest point of the circuit, where it escapes through the vent pipe.



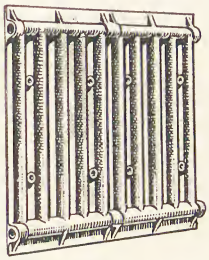
FRONT VIEW



BACK VIEW with Waterways.



FRONT VIEW



BACK VIEW with Waterways.

Fig. 4.—Two typical examples of plate panels

It is the practice to weld all the pipe joints in panel heating schemes, as there is a risk of serious damage by water if a leak should develop in the embedded pipes.

The control valves are enclosed in boxes having removable or hinged covers. The boxes are fixed with the covers flush with the plastered wall face, and in this way the valves are accessible for adjustment or repairs.

Reference should be made to the manufacturers' publications for particulars of the heating effect of plate panels, but there are so many factors affecting the transmission from the plaster-embedded type that no definite figure can be given without a number of qualifying conditions.

For rough approximations of the panel surface, between 80 and 90 B.Th.U. per square foot may be taken for average conditions.

Floor Heating

Another successful form of invisible heating, and one which some authorities hold is preferable to the ceiling or wall panel method, is floor heating. An example of this is to be found in Liverpool Cathedral, where heated air is conducted through an arrangement of small air passages formed immediately below the surface of the floor. This is really a modern application of a system used by the Romans, who constructed horizontal smoke flues under the floors of their villas for the same purpose. Floor heating by hot-water pipes instead of warm air has also been installed with satisfactory results in several open-air schools, and

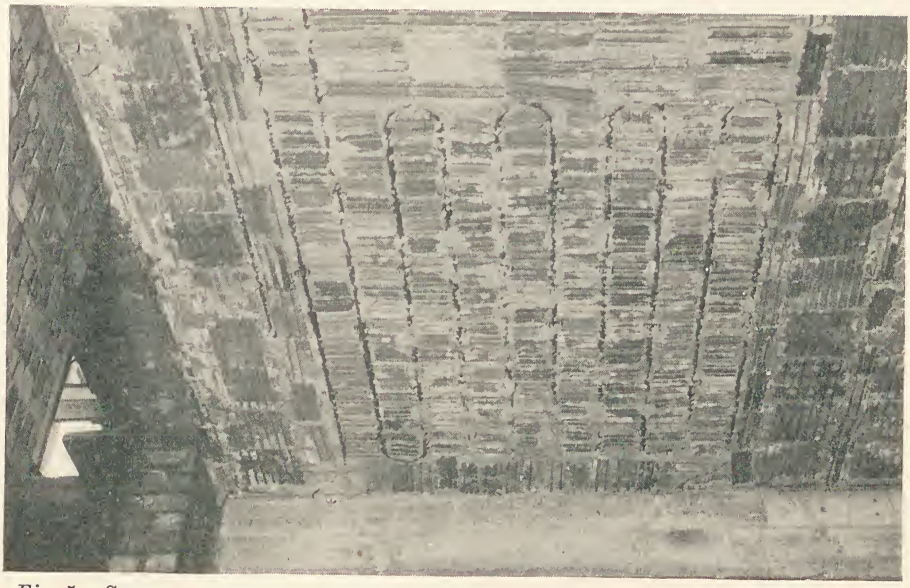


Fig. 5.—SOFFIT OF CEILING IMMEDIATELY AFTER REMOVAL OF SHUTTERING, SHOWING EMBEDDED PANEL COIL

it is particularly suitable for large entrance halls to public buildings, etc., where any visible form of heating might clash with the architectural and decorative features.

Automatic Stokers

Where automatic firing by solid rather than liquid fuel is to be provided, there is a number of automatic stoking machines now available. The most common type is the under-feed pattern, which conveys the coal from a hopper or container to a retort fixed below the fire inside the boiler. The conveyor is a large screw or worm, driven from a motor which also drives a fan for the air supply. The various components are assembled to form one unit, which is placed at the front or side of the boiler. The side is the better position, as it gives an unobstructed access to the firepot for the removal of clinker.

The hopper is of stout sheet steel, and should have a capacity equal to approximately twelve hours' fuel consumption. The worm conveyor passes through the hopper at the bottom and terminates at the retort. The coal is carried in a stream by the conveyor to the bottom of the retort, where it is pushed upward. The fire is therefore fed from beneath the incandescent top layer, and the fresh fuel is gradually heated in its approach to the fire. An air supply is maintained through ports in the upper part of the retort, and this, mixing with the gases from the heated coal, forms a combustible mixture which is ignited on passing through the

incandescent coals. The complete combustion thus obtained eliminates smoke and increases the efficiency of the plant.

Bituminous or anthracite coals can be burnt satisfactorily, and the only attention necessary is to fill the hopper and remove the accumulation of clinker once or twice daily.

Thermostatic and/or pressure controls and relay switches are provided to permit of automatic operation.

In addition, a time switch is usually fitted. This automatically starts the machine running for a few minutes at set intervals. By such means the fire is kept alight when the stoker has been cut out for long periods by the room thermostat. It is also used to operate the stoker intermittently during the night or week-ends.

Boilers

The most common type of boiler used for central heating by low-pressure hot water is the cast-iron sectional boiler, and there are many reasons for the engineer's choice of this type.

The variety of patterns and sizes available enables a suitable boiler of the correct rating to be selected for installations having heating loads of from 20,000 B.Th.U. per hour and upwards by every few thousands to over 1,000,000 B.Th.U. The boilers are cheap and efficient and their lifetime frequently exceeds 15 years. Repairs are easily effected by the replacement of the faulty section or sections ; by the addition of sections the installation can be extended without having to replace the entire boiler.

The sections are tested by most manufacturers to a hydraulic pressure of 100 lb. per square inch, so that the boilers are suitable for systems working under static heads up to 120 ft. Except for the very small patterns the boiler sections are assembled on site, and for their assembly push nipples are used, usually three for each section. In some types the sections are pulled close together so that there is a metal-to-metal contact, in others a space of about $\frac{3}{8}$ in. is left between them which is afterwards filled in by asbestos rope or boiler putty. Water-cooled firebars are a feature in the patterns of some manufacturers, while others continue to use the ordinary loose cast-iron firebar. Nearly all patterns can be fitted with insulated steel jackets, which are an improvement on unprotected plastic non-conducting composition in that there is less possibility of damage to the boiler insulation.

The heating surface of a boiler may be classified under two headings, Primary and Secondary. The primary surface is that which receives the heat direct from the fire and the secondary surface is that which receives the heat from the gases on their way from the firebox to the chimney. In the cast-iron heating boiler approximately 50 per cent. of the surface is primary, and the remaining 50 per cent. is the secondary surface in the boiler flues. The proportion of secondary surface is

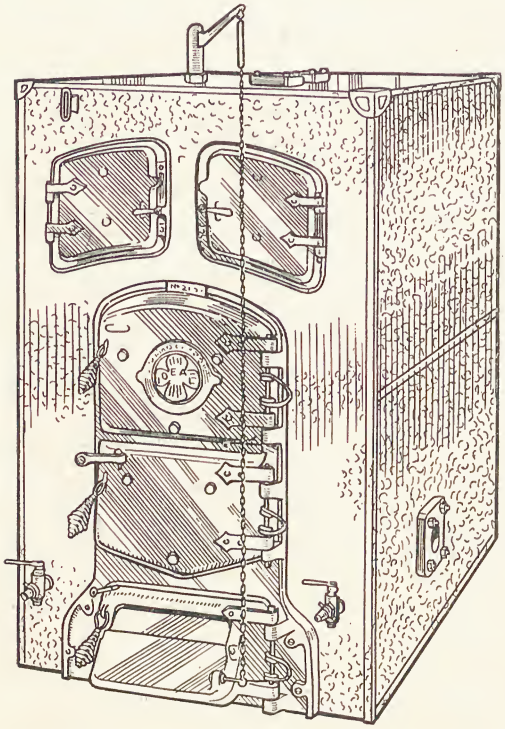


Fig. 6.—SECTIONAL BOILER, COVERED WITH INSULATING GALVANISED STEEL JACKET

calculated to improve the efficiency of the boiler by reducing the temperature of the gases, which should leave the boiler at temperatures in the neighbourhood of 500° F. If lower temperatures were obtained the draught would be impaired and troubles might be experienced from condensation.

The efficiency of this type of boiler under laboratory test conditions is often as high as 75 per cent., but a percentage of 60 may be considered good for average working conditions.

Boiler Ratings

The B.Th.U. output of any boiler is obviously dependent upon the amount of fuel burnt per hour, the calorific value of the fuel, and the capacity of the boiler to absorb the heat generated by the combustion of the fuel. As all these factors are variable an agreed standard rating is desirable for the guidance of the engineer in his selection of a boiler. The makers' lists, therefore, give the heating capacity of cast-iron boilers based on a rated transmission of 4,400 B.Th.U. per hour per square foot of heating surface in the boiler. This figure is used as representative of the average rate of transmission under normal working conditions and for a fuel charge once in six hours.

It is good practice to add at least 25 per cent. to the net requirements of a heating system when calculating the boiler power ; this will make certain that the boiler is of ample capacity for the installation even under the most severe winter conditions.

Magazine Boilers

The high initial cost of an automatic stoker plus the cost of a boiler for automatic firing equipment has resulted in the successful development of the magazine or gravity-feed boiler.

In this type of boiler, the fuel, which may be either coke or anthracite, is placed in the boiler in sufficient quantities for a continuous firing

period of perhaps ten or twelve and sometimes twenty-four hours, and feeds automatically on to the grate according to the rate of combustion.

The draught is sometimes maintained by a motor-driven fan, which, as it can be controlled by electrically operated thermostats, regulates the volume of air. The quantity of air delivered to the grate obviously affects the combustion of the fuel, and the heat output is therefore regulated by varying the air-supply.

In boilers designed for natural draught, a thermostatically controlled damper is actuated to control the volume of air.

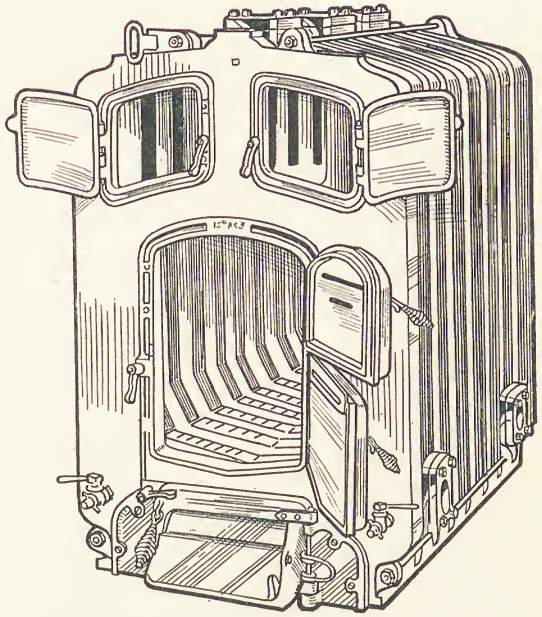


Fig. 7.—CAST-IRON BOILER, BUILT UP IN SECTIONS

In the various designs now available, there are individual features which the makers claim are distinctive and improvements upon the designs of boilers of rival manufacture. The underlying principles common to all, however, are automatically controlled combustion and fuel storage by which hand firing is eliminated, and the boiler attendant's services are required only once or twice daily.

Test results show very high percentages of efficiency, varying from 75 to 90 per cent. The claims made that running costs are exceptionally low, in both fuel and labour, may, therefore, be considered justifiable.

Where possible, the fuel store is situated immediately above the boiler chamber, and chutes are arranged to discharge directly into the fuel space in the boiler.

Calorifiers

The steam-heated calorifier for low-pressure hot-water heating is obviously the choice of the engineer if steam is available. It is used largely in hospitals and similar institutions where steam is generated for other purposes. By its use, the heat in exhaust steam, which might otherwise be wasted, can be utilised and considerable economy effected.

In its construction, a battery of tubes is fixed inside a cylindrical casing and a steam chest is bolted to one end. The tubes are usually of copper and are bent into a U-shape, the ends being expanded into a

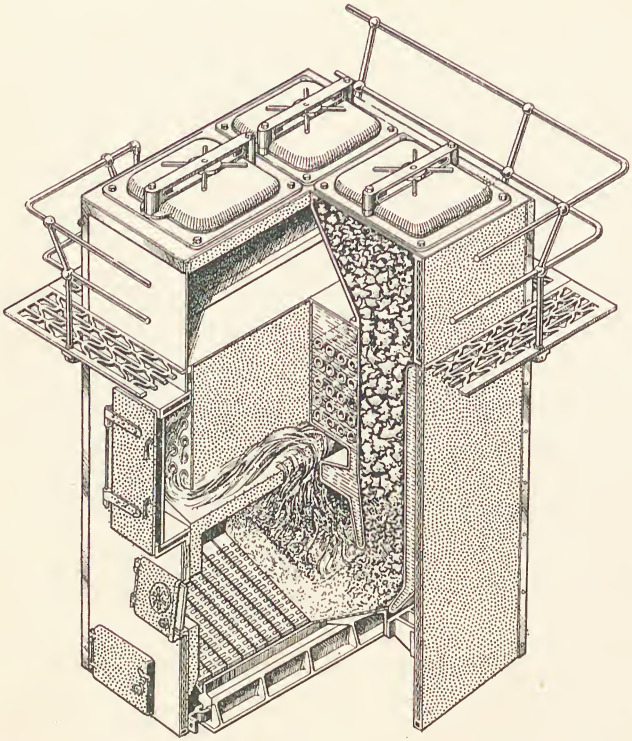


Fig. 8.—TYPICAL EXAMPLE OF MAGAZINE OR GRAVITY-FEED BOILER

mild-steel or brass tube-plate. Branches are provided on the steam chest for the steam inlet and condense outlet, and on the cylindrical casing for the flow and return pipes and usual mountings.

The transmission of heat through the tubes, from the steam to the water, depends upon the difference in the temperatures of these elements.

How the Heating Capacity is Found

The heating capacity is found by multiplying the amount of steam-heated surface provided, by the factor of transmission used for the particular conditions of temperature difference.

By way of example, consider a calorifier that is to have a rated output of 500,000 B.Th.U. per hour, and that copper tubes are to form the heating surface. The mean steam-pressure is 5 lb. per sq. in., and the mean temperature of the water in the heating system 160° F. The temperature of steam at 5 lb. per sq. in. = 220° F., then the temperature difference between the steam and water = 220 — 160 = 60° F.

For a temperature difference of 60° F., the factor of transmission for copper pipes may be taken as equal to 9,500 B.Th.U. per sq. ft.

The heating surface required is, therefore,

$$\frac{500{,}000}{9{,}500} = 53{\cdot}68 \text{ sq. ft.}$$

For the same output and a steam-pressure of 50 lb./sq. in. the heating surface necessary would be only 14·3 sq. ft.

This amount is arrived at as follows :—

Steam temperature at 50 lb. pressure	= 298° F.
Mean water temperature	= 160° F.
Temperature difference	= 138° F.

A reasonable factor of transmission for this temperature difference is 35,000 B.Th.U. per sq. ft.

$$\text{Then, heating surface required} = \frac{500{,}000}{35{,}000} = 14{\cdot}3 \text{ sq. ft.}$$

The actual factors of transmission used by calorifier makers are based on their own tests, as the manner of grouping the tubes and other conditions affect the rate of heat exchange. It is not possible, therefore, to give definite values of " K " (the letter used to indicate transmission factors).

Automatic Steam-control Valves

In addition to the usual mountings, it is good practice to fit automatic steam-control valves on the steam inlets to heating calorifiers. Such valves are governed by the flow temperature, and can be adjusted within limits so to control the quantity of steam entering the calorifiers that the flow temperature is maintained at a constant level.

The steam traps fitted should be of ample capacity for the required duty, and it is better to err on the large side when deciding upon the size to use.

The steam and water ways of all heating calorifiers should be tested at works to a hydraulic pressure of not less than twice the normal working pressure. The tubes should be solid-drawn and not less than 18 gauge thickness.

Boiler Mountings

The usual mountings for any well-designed hot-water boiler installation should comprise a safety valve, thermometer, altitude gauge, damper regulator and emptying cock.

Safety Valve

The safety valve should be of ample area at the valve seat, and loaded to approximately 25 ft. in excess of the actual working head, but not exceeding the

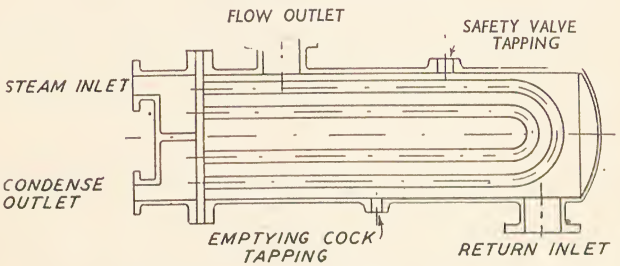


Fig. 9.—SECTIONAL ILLUSTRATION OF STEAM-HEATING CALORIFIER

boiler test pressure. It should be attached directly to the boiler without any intervening fitting such as a valve.

Thermometer

The thermometer should be graduated from 60° F. to 240° F. and should have the bulb encased in a metal pocket to withstand the pressure. Care should be taken that, when fitted, the pocket is immersed in the water and that it is filled with mercury. It is usual to fix the thermometer at the front of the boiler where it can be easily read, but a more correct reading of the actual flow temperature is obtained by fixing it close to the flow-pipe branch or in the flow pipe itself.

Altitude Gauge

An altitude gauge is an indicator of the pressure or head of water at the boiler and is constructed in the same way as the ordinary steam-pressure gauge. The dial should be graduated in feet-head of water to approximately twice the working head, and fitted with a red pointer. As with safety valves, altitude gauges should be fixed so that direct contact is made with the water in the boilers. The red pointer is adjusted to the normal pressure and acts as an indicator of the correct working head.

If the water-level falls or excessive pressures are set up, the position of the black pointer either to the left or right of the red pointer gives warning to the attendant that investigation is necessary to locate the cause of these vagaries.

Automatic Damper Regulator

The automatic damper regulator is a useful fitting to include in the list of boiler mountings, as by it the air supply to the grate is controlled and the rate of combustion regulated. The regulator is screwed into a tapping at the top of the front boiler section and is fitted with a movable lever. A chain attached to the lever is hooked to a hinged draught-door fitted to the boiler ashpit door. As the temperature of the boiler increases or decreases the lever arm drops or rises and actuates the draught-door, so that the air supply is regulated accordingly.

HEATING AND VENTILATION

PART V.—STEAM HEATING, OIL BURNERS

THE mains used in steam pipe-lines are usually of wrought iron or mild steel and are heavier than those used in hot-water heating ; the thickness of the tube walls is increased by one wire gauge. The manufacturers always paint steam-quality tube red, so that it is easily distinguished from the " blue " water-quality tubing.

The joints may be screwed and socketed or flanged. Flanged joints only should be used on high-pressure work and where strains are likely to be set up in the pipe-line. The flanges should be of mild steel, and the thickness, diameters and drilling in accordance with the British Standard Table applicable for the particular working steam-pressure. They are either screwed on to the pipe ends, which are afterwards expanded, or welded. In making the joint, a corrugated brass ring is coated with jointing compound and inserted between the flanges. The bolts are then tightened.

Special Joint-rings

Asbestos and special compound joint-rings are often used instead of the brass corrugated rings. Where screwed joints are made, a thin coating of jointing compound is applied to the threads. Hemp wound on to the threads will not assist in making a permanent steam-tight joint, and should never be used.

The pipes are best supported on brackets fitted with rollers or designed to allow free movement when expansion takes place.

The heat given up by the steam-heated pipe results in the formation of water by condensation. It is important that this water should not collect in the main, or serious knocking known as water hammer will develop. The pipes, therefore, should be fixed with a fall in the direction of the flow of steam of not less than $\frac{1}{4}$ in. in 10 ft., and at suitable intervals drain pockets should be provided.

Formula for Sizing Steam Pipes

A formula in common use for sizing steam pipes is that which gives

$$W = 87{\cdot}5\sqrt{\frac{Pyd}{L\left(1+\frac{3{\cdot}6}{d}\right)}}$$

where W = lb. of steam per minute.
P = Drop in pressure in length L.
d = Diameter of pipe in inches.
y = Density of steam, lb./ft.^{3}
L = Length of pipe in feet.

In the following Table, the flow of steam in lb. per hour is given for various sizes of pipes for steam-pressures from 1 to 100 lb./sq. in.

Pressure lb./sq. in.	*Flow of Steam Through Pipes*						
	Diameter of Pipe						
	¾ in.	1 in.	1½ in.	2 in.	2½ in.	3 in.	4 in.
	Weight of Steam in lb./hour with 1 lb. Drop/100 ft.						
1 .	26·9	55·4	186·9	390	654	1,180	2,515
10 .	33·4	68·9	232·1	483	813	1,465	2,580
20 .	39·5	81·0	275·5	567	955	1,717	3,660
30 .	43·6	91·1	308·0	640	1,075	1,930	4,125
40 .	48·8	100·3	338·0	703	1,183	2,125	4,540
50 .	52·7	108·4	368·0	763	1,275	2,300	4,910
60 .	56·4	115·7	390·0	811	1,365	2,455	5,240
70 .	59·7	122·8	413·0	862	1,445	2,610	5,570
80 .	62·9	129·2	436·0	905	1,523	2,735	5,830
90 .	65·7	135·0	455·0	947	1,590	2,865	6,110
100 .	68·5	140·8	475·0	985	1,653	2,980	6,370

Estimating Quantity of Steam Required

In estimating the quantity of steam required for a heating system, the B.Th.U. requirements should first be determined. Then, since the latent heat of steam for pressures between 1 lb. and 100 lb./sq. in. is from 970 to 900 B.Th.U./lb., for practical purposes and easy approximations it is sufficient to divide the B.Th.U. by 1,000 to obtain the amount of steam in pounds per hour.

Condense

The condense water formed in any steam-heating system should, wherever possible, be carried back to the boiler. Failure to do so will result in uneconomic running costs, as cold fresh water must be supplied to make good the loss.

This water has, of course, to be heated up from, say, 50° F., and fuel costs, therefore, are unnecessarily high. By collecting the condensate, water consumption is lowered, and as the temperature is often as high as 180° F., the fuel consumption is also reduced. The formation of scale in the boiler, especially in hard-water districts, is also retarded.

It is advisable to use copper piping throughout the condense pipe-line because of the corrosive action of condensate upon mild steel. Cast-iron pipes do not suffer greatly from this corrosive action and are quite suitable for the larger sizes.

The quantity of condense water is of course equal in pounds to the pounds of steam condensed; reference to the pipe-sizing charts for hot-water heating will assist in the determination of the sizes of the condense mains.

In open return systems the condensate gravitates to a tank or hot well in the boiler house, and this is used as a reservoir from which the boiler-feed pump obtains the water to be delivered to the boiler.

In low-pressure closed systems, the condensate is returned direct to the boiler without the assistance of the boiler-feed pump. Any losses of water are made good by the provision of an automatic boiler-feeder which maintains a constant water-level in the boiler.

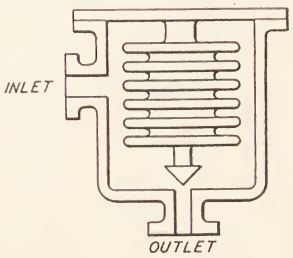


Fig. 1.—EXPANSION STEAM TRAP

This form of trap is fitted on steam radiators and heaters owing to its compact design.

Steam Traps

These important fittings are fitted to most steam-heating equipment with the exception of small, closed-return systems. In their action they serve a double purpose: (1) to drain the pipes and heaters of the condensed water, and (2), to prevent the escape of steam from the condense outlet.

The types of traps in general use are those known as :—

(1) The expansion type, and

(2) The open or closed float pattern.

Expansion Type of Trap

In the expansion type, the trap valve is opened and closed by the contraction and expansion of an element sensitive to varying temperatures. Thus, as water is formed and becomes cooler than the steam, it flows out of the trap. Immediately steam reaches the trap, the increase in temperature causes the expansion of the element, and the trap closes.

This form of trap is fitted on radiators and heaters largely because of its compact design and neat appearance. They are usually fitted with a union connection on the inlet side, and can be supplied in polished chromium-plated finish.

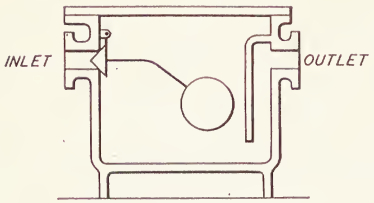


Fig. 2.—CLOSED-FLOAT TRAP

Where there is a number of traps of this type in use on a particular installation it is advisable to provide spare elements, which can be used to replace any that may fail to operate satisfactorily after a long period of continual expansion and contraction.

Float Traps

One of the most commonly used closed-float patterns comprises a cast-iron vessel, with inlet and discharge branches for the connecting pipework, and a bolted-on cover. The float is of copper and is fixed to a lever, at the end of which a hinged valve is attached. A small V-notch is cut into the valve face. In action, the condensate trickles through the V-notch until sufficient water has accumulated in the trap to lift the float. The float, on lifting, opens the valve, and water flows through until steam enters. The pressure of the steam continues to discharge the water until the level drops, lowering the float and thereby closing the inlet. Steam is prevented from blowing through the trap by locating the outlet, internally, near the bottom, so that a water seal is formed.

The area of the orifice at the inlet is calculated to prevent the steam pressure from forcing open the valve.

In the open-float trap, the float, or bucket as it is sometimes called, is attached to a valve which opens and closes the outlet as the float rises and falls. In some patterns, the floats are inverted.

In action, water enters the trap until it overflows into the float and by reducing its buoyancy causes it to drop ; the pressure of the steam then forces the water up the discharge pipe. The float again becomes buoyant, and on rising closes the valve.

It is important that all traps should be suitable for the working steam pressure, and that they are of sufficient capacity. The manufacturers usually ask for full particulars of the conditions under which a particular trap has to work, and are then able to supply one most suitable for such conditions.

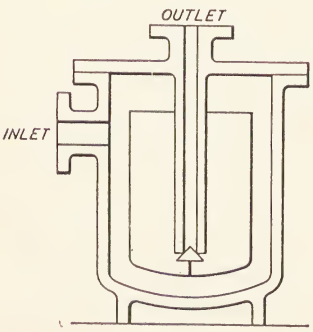


Fig. 3.—OPEN-FLOAT TRAP

Siphon-pipe Trap

A device for trapping steam is shown in Fig. 4, which illustrates a simple siphon pipe. This arrangement is satisfactory for low pressures, and is favoured by many engineers, as there are no valves or moving parts which, through neglect or other causes,

may result in the failure of a trap to operate satisfactorily.

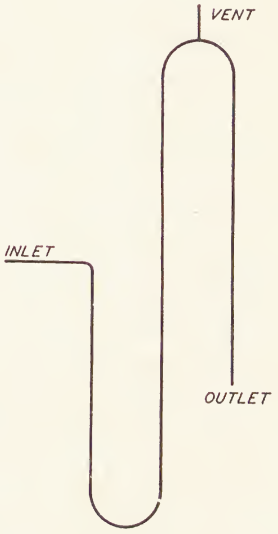


Fig. 4.—SIPHON-PIPE TRAP

Valves

Steam stop-valves are generally of the screw-down pattern, and for small sizes are constructed throughout of bronze or gun-metal. Valves above 2½-in. diameter usually have cast-iron bodies, fitted with valves and seats of gun-metal or special alloy.

Care is necessary in the selection of a valve, to be certain that it is suitable for the conditions under which it has to operate. It should not only be robust enough for the pressure, but also be designed to withstand the effects of the temperature, which, as will be seen by referring to steam tables, rises rapidly as the pressure increases. For instance, at atmospheric pressure the temperature is 212° F., but at 50 lb. gauge pressure the temperature is 297·5° F.

The glands are packed either with asbestos cord, or with special packing which will not deteriorate when heated to the steam temperature.

Main steam valves should have flanged branches, and if subject to high pressure the screws on the spindles should be outside.

The hand wheels, especially on small control valves, are often made of some non-conducting material, in order that they remain sufficiently cool to handle comfortably.

Steam-pressure reducing valves are necessary where plant, not suitable for the higher pressure probably required elsewhere, is to be supplied with steam. There are numerous patterns available and, as with steam traps, it is advisable to supply the manufacturers with full particulars of the required duty of each valve. Every reducing valve should be fitted with a pressure gauge on the reduced-pressure side, and a pressure-relief valve. As periodical attention and examination are necessary, a stop-valve should always precede a reducing valve.

Drain and Dirt Pockets

The expansion and contraction of new steam pipes cause the flaking of scale from the internal sides, and this, with other matter such as small quantities of jointing compound, often results in the blocking of small steam and condense pipes unless precautions are taken to avoid it.

One method is to form a well or pocket in the steam main, similar to that shown in Fig. 5. This serves the double purpose of a receptacle for the condense and for any deposit of solids.

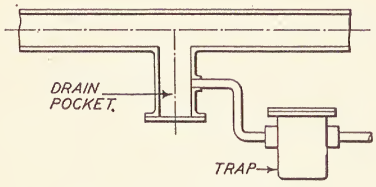


Fig. 5.—DIRT AND DRAIN POCKET IN STEAM MAIN

The outlet for the condense is placed about half-way down the pocket, and by the provision of a flanged joint or plugged outlet any accumulation of solids can be removed without breaking the joint of the connecting pipework to the trap.

The provision of perforated-metal or fine-mesh wire baskets in the steam main is sometimes desirable as a precaution against possible damage to reducing valves, meters, or other steam-operated fittings. Such baskets, or strainers as they are usually termed, are housed in special castings fitted with inspection covers which, on removal, allow the strainers to be taken out and cleaned. Fig. 6 illustrates a typical pattern.

Expansion Fittings

The coefficient of linear expansion of mild steel or wrought iron is $6{\cdot}6 \times 10^{-6}$ per degree F. Therefore, if a mild-steel steam pipe 100 ft. long is heated from, say, 50° F. to 300° F. (steam temperature at approximately 52 lb. gauge pressure), its increase in length will be :—

$$\begin{aligned} &{\cdot}0000066 \times 100 \times (300 - 50) \\ &= {\cdot}00066 \times 250 \\ &= {\cdot}165 \text{ ft. or } 1{\cdot}98 \text{ in.} \end{aligned}$$

It is necessary to make provision for an increase in length in long straight runs of steam-heated pipe by inserting suitable expansion joints or bends.

An expansion joint is made by permitting the free end of one pipe to slide in the socketed end of another, through a steam-tight gland. Such joints require frequent repacking of the glands, and are not favoured by most engineers.

Expansion loops are made by bending the pipes into the shape of a horseshoe, and although they take up more space than the sliding joint, are more satisfactory, particularly in pipe ducts and other places where access to them is difficult. They must, of course, be fixed horizontally, and in high-pressure mains at intervals of 40–60 ft. For low-pressure mains, the distance between the expansion bends may be increased to 80–100 ft.

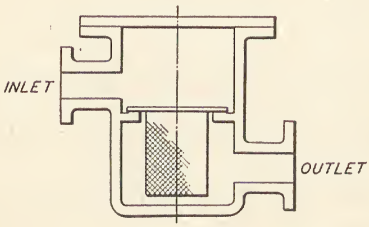


Fig. 6.—STRAINER IN STEAM MAIN

The following diagram and Table give useful data in relation to a typical form of expansion bend.

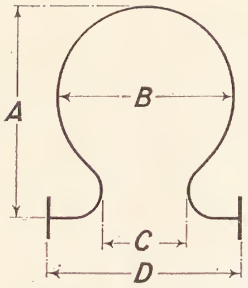


Fig. 7.—EXPANSION LOOP

DIMENSIONS OF EXPANSION LOOPS

Diameter	*A*	*B*	*C*	*D*
in.	*ft. in.*	*ft. in.*	*in.*	*ft. in.*
1	1 1½	9	1¾	1 3
1½	1 6¾	1 0	2⅛	1 8
2	2 0	1 3	2⅝	2 0
2½	2 5	1 6	3½	2 5½
3	2 10	1 9	4½	2 10
4	3 9	2 4	6½	3 8
5	4 9	2 11	8½	4 6
6	5 8	3 6	10	5 3½

Unit Heaters

The satisfactory heating of a workshop or warehouse by ordinary hot-water pipes or radiators has always presented difficulties to the engineer, because of the problems of available floor space, and the location of the heating surface in positions where its effect would not be impaired by surrounding machinery or shelving. Overhead pipes and systems of warm-air ducting are, therefore, frequently introduced.

A recent and successful method that has been widely adopted, however, is one in which small batteries of heated pipes are fixed overhead. To each battery a fan is attached, and the combined fan and heater unit distributes warmed air over the area within the limits of its range.

It is claimed that by this method economies are effected in pipework, and in leaving the floor space clear of heating equipment. By the proper distribution of unit heaters, large-area workshops, etc., can be heated uniformly without interfering with the layout of machinery, and structural alterations to an existing building are also eliminated.

In the construction of a unit heater, gilled tubes of copper are grouped together and framed in a sheet-metal casing. On the inlet side, an electrically driven propeller-fan is bolted to the frame. The motor is of the totally enclosed type, and is of fractional horse-power consuming no more than 50 watts on the smallest-sized heaters, and up to 400 watts on the largest units.

On the discharge side, louvres are provided and set at a downward angle to direct the air towards the floor. Some manufacturers make the louvre blades adjustable, so that the direction of the air stream can be regulated. The height of the heater, and the area served by it, make the adjustable feature desirable if the most effective results are to be obtained.

The gilled tubes are suitable for a wide range of pressures up to 100 lb. per square inch, and in some cases are tested after assembly to a hydraulic pressure of 300 lb. per square inch.

Number and Size of Unit Heaters Required

The heating capacities depend upon a number of conditions, such as the temperature of the air entering the heater, the volume delivered, and the pressure of the steam. The makers usually tabulate the various outputs of each size, in their catalogues, giving B.Th.U. per hour, steam consumption, outlet air temperatures, volume of air delivered, entering air temperature, and steam pressure.

It is, therefore, a simple matter to determine the number and size of the heaters required, after the heating requirements of the building have been calculated.

The disposition of the heaters should receive careful consideration, and the runs of the pipework so planned that the completed installation has a neat appearance. Most makers of unit heaters are prepared to submit schemes showing their own methods of setting out the heaters to the best advantage.

Thermostatic controls are a refinement well worth the small additional initial cost, as by their use the room temperatures are maintained at the required level, and economy in electrical consumption is effected.

OIL FIRING

The unsettled conditions in the coalfields some years ago gave an impetus to the sale of oil burners for central heating and hot-water-supply boilers. There were already several good burners, chiefly of American manufacture, on the market, and a number of existing solid-fuel burning installations were changed over to oil-fired systems. Since that time, a number of British-manufactured burners have been introduced and the contracting engineer has now a large variety from which to make his selection.

The Oil Burner

The essential components of an oil burner are :—

(1) A pump for forcing the oil through the burner nozzles.

(2) An atomising device for breaking up the oil into small particles, so that a fine mist is formed.

(3) A fan or air compressor to supply the required quantity of air for satisfactory combustion.

(4) An ignition system using either gas or electricity.

(5) A motor for driving the pump and fan.

The modern burner, besides containing these essentials, incorporates a comprehensive arrangement of controls which enables the owner to put the plant in operation simply by closing a switch, which may be placed in any convenient position in the house. The burner will then continue to operate automatically, starting and stopping as the heat demand fluctuates. Periodical attention is necessary to ensure that a correct flame is produced, and a general overhaul by a competent service man

should be made at intervals of not longer than three months if the burner is in continuous use.

Storing the Oil

The oil may be stored in cylindrical or rectangular tanks of sufficient capacity for a period of from two weeks to a month. In country districts, where there is no frequent delivery service, it is sometimes advisable to provide a tank of approximately five tons' capacity. A four-ton lorry can then deliver its full load of oil, and delivery charges are thereby lower than if smaller quantities are supplied.

The cylindrical tanks can be buried in the ground in a similar manner to tanks for the familiar petrol-filling stations. The tank is lowered on to suitable concrete settings so that it takes up a position slightly off the horizontal. At the lower end, a pipe is carried down inside for emptying purposes, and for the removal of water and sludge which accumulate occasionally.

Other pipe connections for the filling, vent, and supply and return pipes to the burner are usually made in the raised manhole cover of the tank. An oil gauge, carefully calibrated from dip-stick readings, should always be fitted.

Rectangular tanks are only used above ground level, and should be enclosed in an oiltight space. Any doorway to the space should be fitted with a fireproof door fixed at a sufficient height for the space below to form a catchpit of greater capacity than the tank.

Safeguards and Controls

In all cases of oil-firing installations, the recommendations of the Fire Offices Committee should be complied with. These recommendations are contained in a publication of the committee dated August 1935.

A feature of an automatic oil-burning plant is the provision of various devices for safeguarding and controlling the system. One comes into operation and stops the motor if the oil fails to ignite ; another is a boiler-temperature control which stops or starts the motor if the flow temperature rises or falls beyond predetermined limits. For heating installations a room control is usually provided. This is fixed in a convenient position in one of the heated rooms, and can be adjusted within limits to various temperatures. On the required temperature being reached, a switch opens and the burner is stopped ; the room temperature may then start to fall and the switch then closes, setting the burner to work again.

It is important that the combustion chamber of the boiler should be of adequate size, and that it be lined with refractory brickwork to the design which the burner manufacturers recommend.

SANITARY SURVEYING

PART IV.—DAMPNESS

ONE of the most common defects found in the older type of houses is dampness ; and this condition may be due to one of a number of causes, such as rising dampness within the walls of the lower floor, penetration of rain through the brickwork or joints, defective rain-water pipes, choked gutters, defective roof slates, tiles, or lead flashings.

Absence of Damp-proof Courses

When surveying the lowest floor (ground floor or basement), and finding the walls of the rooms are covered up to dado height with match-boarding or some such material, the surveyor will at once suspect dampness and that the woodwork has been placed there to cover up the unsightly evidence. It is, of course, no cure, but just a camouflage, and he will make a close inspection to find out the cause of the dampness, should such be present.

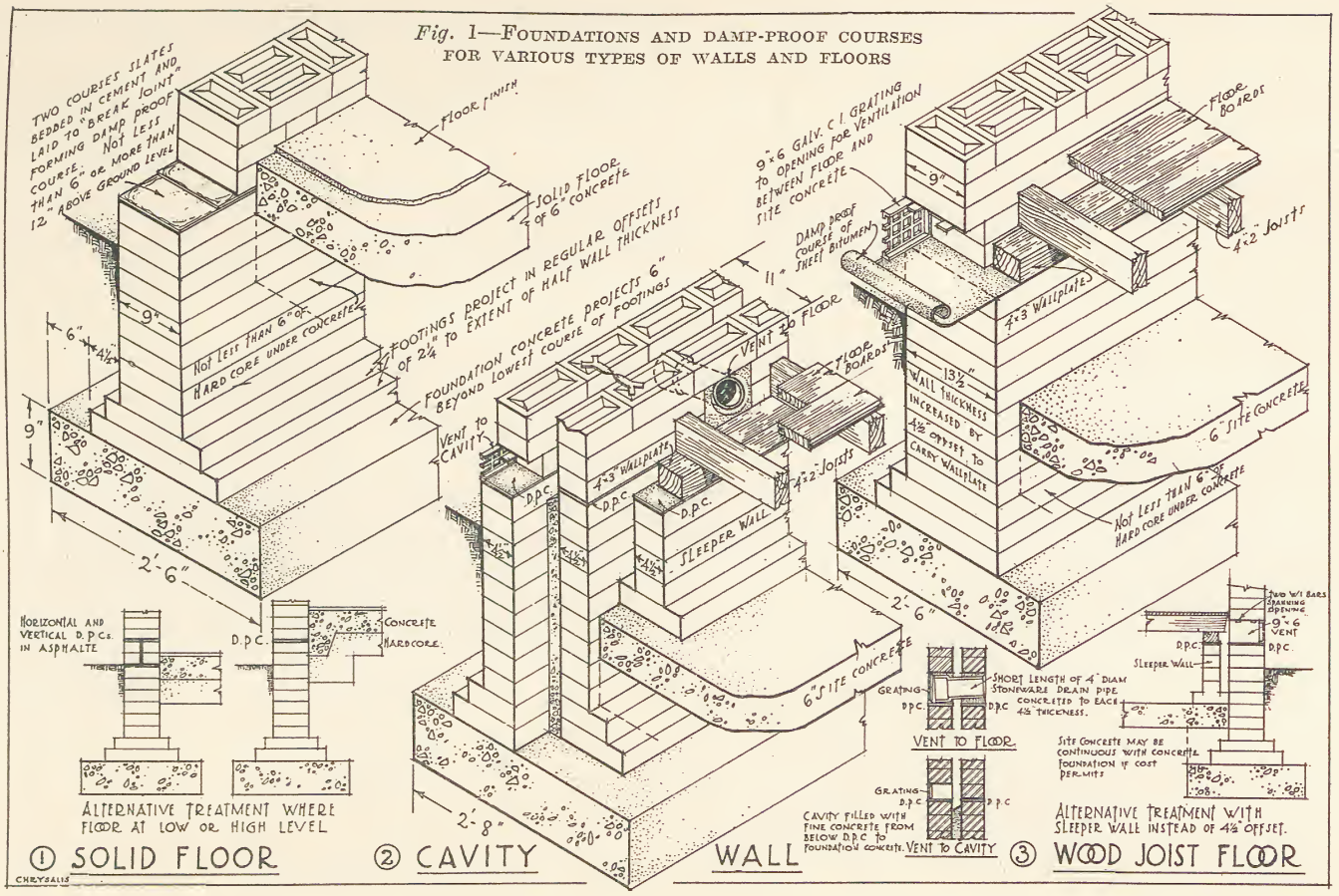
If the rooms have been closed for some time, the characteristic smell of damp walls will be present, but further evidence must be sought by removing a portion of the woodwork to inspect the wall, or by closely examining the lower part of the woodwork or the skirting, and, assuming the wood dado has been installed for some time, one will notice a shrinkage of the wood, which will allow the blade of a penknife to penetrate its substance with ease.

Should the house be of a non-basement type, a horizontal damp-proof course should be in evidence on examination of the brickwork from the outside, and at a position just below the ground-floor level. The Buildings Act requires that it must be inserted at least two courses of brickwork above ground level.

Dampness Caused by Rockery against Wall

If the dampness is confined to the external walls, it does not follow that a damp-proof course has not been installed, for the writer has found a number of instances where such has not been the case, but that the dampness has been solely attributable to the fact that the garden flower bed has been made up to above the damp-proof course, but has, in consequence, conveyed moisture to the brickwork. It is quite common

Fig. 1—FOUNDATIONS AND DAMP-PROOF COURSES FOR VARIOUS TYPES OF WALLS AND FLOORS



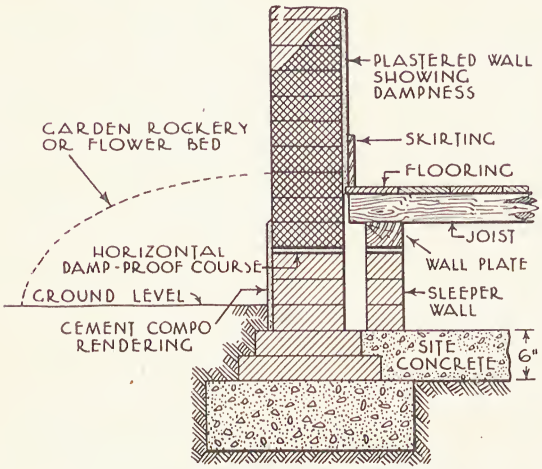


Fig. 1A.—DAMP WALL DUE TO GARDEN FLOWER BED OR ROCKERY INSTALLED ABOVE DAMP-PROOF COURSE

practice for the occupier to build up a rockery against the wall of the house, above the damp-proof course, which must necessarily lead to a damp wall (Fig. 1A).

If the house has a basement floor and dampness is in evidence, it may be necessary to remove a portion of the flooring to assure oneself that a horizontal damp-proof course does or does not exist, as the dampness may be attributable to the absence of a vertical damp-proof course, which is of equal importance when the basement outer wall abuts damp ground.

Installation of Horizontal Damp-proof Courses

Where dampness is attributable to the absence of damp-proof courses, the surest way to remedy the nuisance (although costly) is to insert them. In the case of a non-basement house, it is possible (after the skirting and surrounding flooring have been removed) to cut out a course of brickwork at a position linable with the bottom of the floor joists for a distance of 2 ft., and to insert the damp-proof material throughout the width of the opening, and make good with 2-in.-thick bricks or vitrified stoneware ventilating bricks, or, as recalled by the writer, 2-in. fire tiles, and, in another case, a complete course of blue

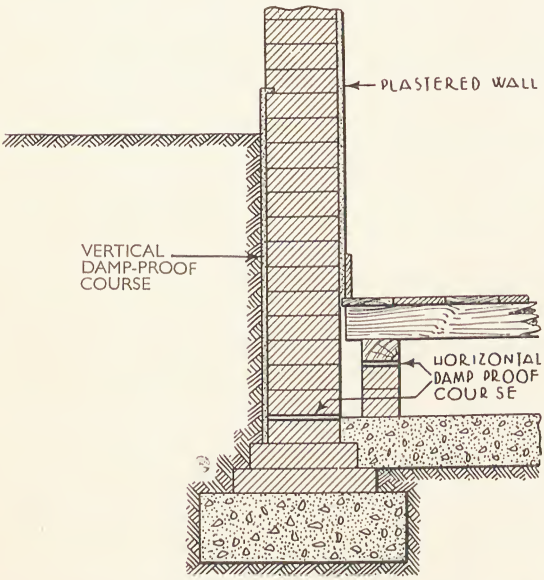


Fig. 2.—POSITION OF VERTICAL AND HORIZONTAL DAMP-PROOF COURSES

Staffordshire bricks. Whichever method is adopted, the making good should be done with Portland cement mortar.

This process should be repeated at several points of the wall, so as to allow the parts treated time to set thoroughly before disturbing adjacent lengths. The most suitable damp-proof courses under these conditions are two courses of slate with overlapping joints set in Portland cement mortar, vitrified stoneware ventilation bricks, or a full course of blue Staffordshire bricks.

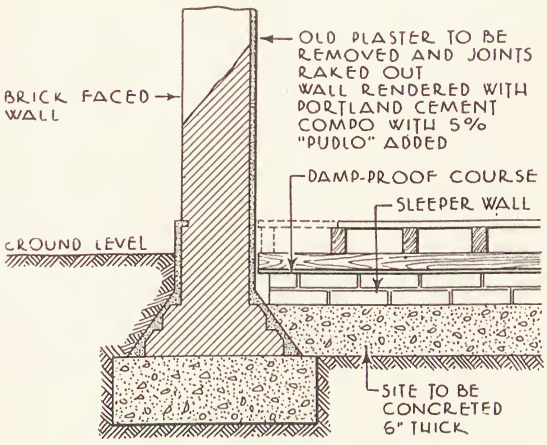


Fig. 3.—DAMP WALL TREATED WITHOUT INSERTING DAMP-PROOF COURSE

Vertical Courses

With regard to the vertical damp-proof course, it will be necessary to excavate the ground adjacent to the damp wall, rake out the mortar at the joints of the bricks, and apply either two courses of slates set in Portland cement mortar, or a 1-in. layer of rock asphalte. Either of the two methods adopted should be taken down to a position below the horizontal damp-proof course (Fig. 2).

Rendered Walls

Although the surest way to remedy the trouble has been illustrated, damp walls have been treated successfully by rendering them on the inside with Portland cement compo and an admixture of 5 per cent. waterproofing material such as "Pudlo," it being necessary to strip the old plaster and coarse stuff from the walls and rake out the joints. The compo should be taken down to the level of the footings or to the level of the surface concrete. If the latter does not exist, it should be installed to a depth of 6 in., beaten to a fluid face so as to render it impervious (Fig. 3).

The success of this method relies upon the external wall being brick-faced and not covered with cement rendering, as is the case with many old town houses, which were erected when Roman cement was extensively used. The moisture contained within the brickwork, through the action of capillary attraction, must have an opportunity to evaporate, which is via the external brickwork, otherwise it is retained and carried to a higher level by the same action.

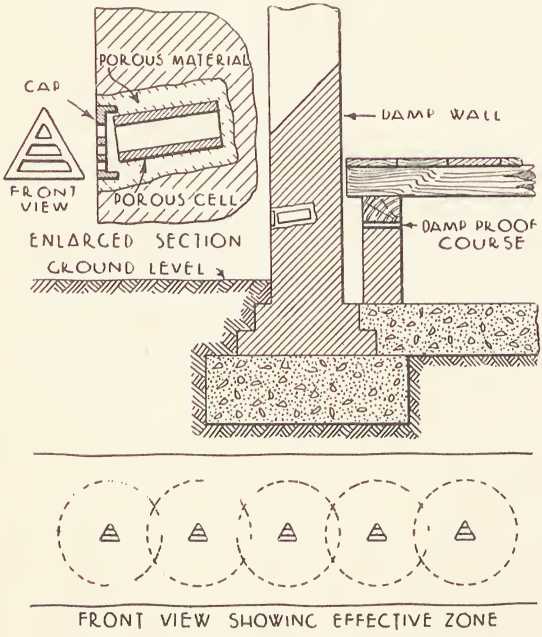


Fig. 4.—DAMP WALL TREATED BY PATENT METHOD OF AERATION

The "Knapen" Method

A patent system of ventilation, known as the "Knapen" method, relies upon air circulating within small porous tubes inserted in the lower portion of the damp wall to take up the moisture caused through the absence of a horizontal damp-proof course. Their frequency of insertion is governed by a prescribed zone through which they are effective, and they are fixed into the wall by means of a porous substance, and provided with a small face cap so as not to be conspicuous (Fig. 4).

Dry Rot

Dry rot is a source of nuisance due to the presence of dampness together with the lack of ventilation. The disturbing factor with regard to dry rot is that of progression. If it is not attended to as soon as noticed, its growth will be extensive where the conditions are favourable. Its effect on timber is to render it devoid of strength, with excessive shrinkage and cracking, while the fungus which is propagated gives off an odour.

Treatment of Dry Rot

The only cure is to take out the affected woodwork and to burn it; then, treat the brickwork and concrete to which the fungus has had access with a disinfectant such as creosote; renew the woodwork, and provide proper through ventilation of the space between the floor and concrete, providing a grating to the openings.

Porous Brickwork

Dampness may be carried through the brickwork due to porosity of the bricks, and, in addition, by the defective condition of pointing. The condition is particularly noticeable where the wall has a south-west aspect, and is subjected to driving rain.

Remedy

There are several methods of dealing with this trouble, one of which is to rake out the joints of the brickwork, and render the face of the affected wall with Portland cement compo (two parts of sand to one part cement). If an artistic face is desired, it can be treated by applying a very fine concrete aggregate, with or without cement wash, and pressed slightly into the face of the compo.

Another method is to rake out the joints of the brickwork and renew the pointing with Portland cement. If the general appearance of the wall is not to be altered, it can be treated with petrifying liquid, which, after two or three coats, renders the brickwork impervious to rain. (There are several patents on the market.) If the appearance of the wall is not a consideration, two coats of oil paint or one coat of tar and pitch will render the wall waterproof.

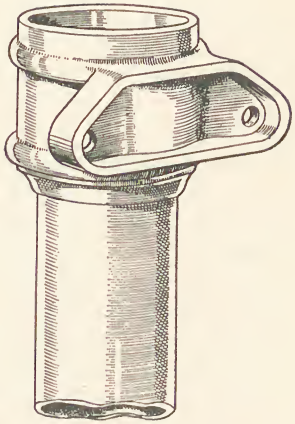


Fig. 5.—TYPE OF CAST-IRON RAIN-WATER PIPE WITH DISTANCE PIECE CAST WITH THE SOCKET

This has the advantage that water from a broken pipe will fall clear of the wall.

Defective Rain-water Pipes

In surveying the rooms, one often finds patches of dampness on the external walls, which is due to the defective condition of the rain-water pipes. In both old and new houses, rain-water pipes are invariably fixed with their sockets close to the wall.

A better method is for the sockets to be kept $1\frac{1}{2}$ in. from the wall by distance pieces, made of odd pieces of $\frac{3}{4}$-in. gas barrel. This will allow the water from a broken pipe or socket to fall clear of the wall, and, in addition, make it possible for the back of the pipe to be painted when redecoration of the house is taking place, thus lengthening the life of the pipe, for it is usually at the back of the pipe or socket that the defect occurs. This obvious defect in fixing has brought on to the market a principle, which can be applied to all classes of cast-iron pipes, of casting the distance pieces with the sockets, at very little extra cost (Fig. 5).

Choked Gutters

Choked or defective eaves gutters may be the cause of patches of dampness in walls, seeing that the blockage allows the rain-water to overflow the gutter, while the wind blows the water on to the wall, thereby saturating the brickwork at that point.

If the construction of the roof is in the form of two half-gables, with a centre lead box gutter, as is often the case in old terrace houses, the partial blockage of the outgo will cause the rain-water to build up in the gutter,

with the result that water will find its way under the lead of the succeeding length of gutter to the ceiling of the room below.

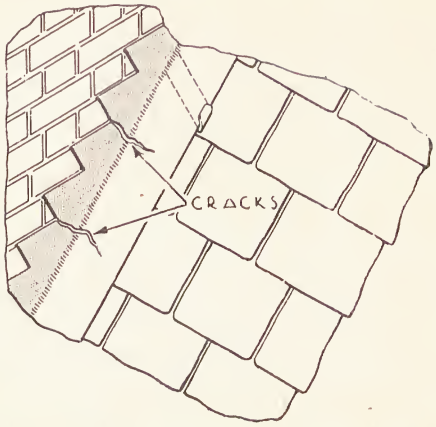


Fig. 6.—SHOWING WHERE CRACKS SOMETIMES DEVELOP IN LEAD STEP AND COVER FLASHING

Slates, Tiles, and Lead Flashings

Defects occurring in roof coverings, such as lead, zinc, asphalte, slates, or tiles, usually show evidence of such defects on the ceilings below. In carrying out a survey it is not sufficient to consider the roof sound if no such evidence exists. An inspection of the roof should be made, noting the general condition of the slates or tiles, and whether any are cracked, slipped from position, or even missing. Where slate ridging or ridge tiles are used, their condition should also be noted.

Flashings or Weatherings

It is necessary to note the condition of all flashings and metalwork generally, as these are subject to movement due to climatic conditions, and if they have not been properly installed, fractures may exist or they may be released from their fixings, thus rendering the roof not watertight (Fig. 6).

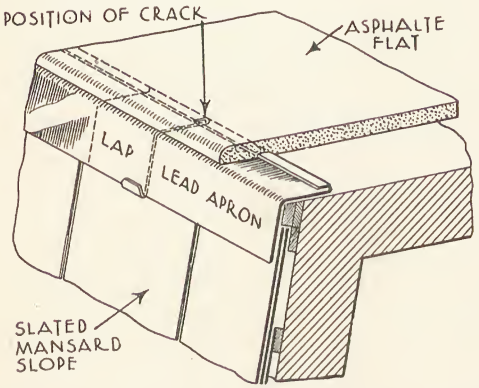


Fig. 7.—LAP OF LEAD APRON TO MANSARD ROOF, WHERE FRACTURES SOMETIMES OCCUR IN THE ASPHALTE

Asphalte Roof

Should the roof be treated with asphalte, inspection should be made, particularly at the base of the skirtings, and also where asphalte is laid over the laps of mansard aprons, as it is at these positions that fractures frequently occur (Fig. 7).

To repair the asphalte, one is best advised to employ a specialist firm, who reheat the existing material, cut out the defective portion, and re-lay, making a perfect union of the edges.

GAS-FITTING AND GAS APPARATUS

VAST improvements in the design and the finish of gas appliances and the considerable extension of the range of all apparatus, backed by nation-wide publicity, have engendered in the mind of the public the desire for the utility service of gas.

Co-operation with manufacturers of gas appliances by gas undertakings has greatly improved the methods of fitting appliances, while the advantages so gained are enhanced by the training of the fitting personnel of undertakings.

The ideal gas installation from the meter outlet has no surface pipework throughout the whole of its carcass. This ideal is easily attainable by builder and undertaking working in unison. Concealed supplies and controls right up to " point " are quite practicable with extant equipment, and adopted where possible in current practice.

Apart from the value of this co-operation to effect smooth working conditions, there can be a material economy in building materials and a great saving of time and labour if the erection of the building and the installation of the gas carcass can proceed in step.

The Gas Installation

Commencing from the distributing main, the sections of the gas installation are :—

(1) The service pipe.
(2) The meter.
(3) The carcass.
(4) The appliance points.

The Service Pipe

Two methods of supply are used for the distribution of gas—the low-pressure system and the high-pressure system. On the low-pressure system the service pipe is taken direct from the main to the control-cock before the meter, with a slope back to the main for the return of condensation. If a locality necessitates any incline of the service away from the main, and dehydration is not practised by the undertaking, a siphon is inserted at the lowest point. Normal domestic requirements are satisfied by a service pipe of 1-in. or $1\frac{1}{4}$-in. size.

On the high-pressure system the service pipe is only of $\frac{1}{2}$-in. or $\frac{3}{4}$-in.

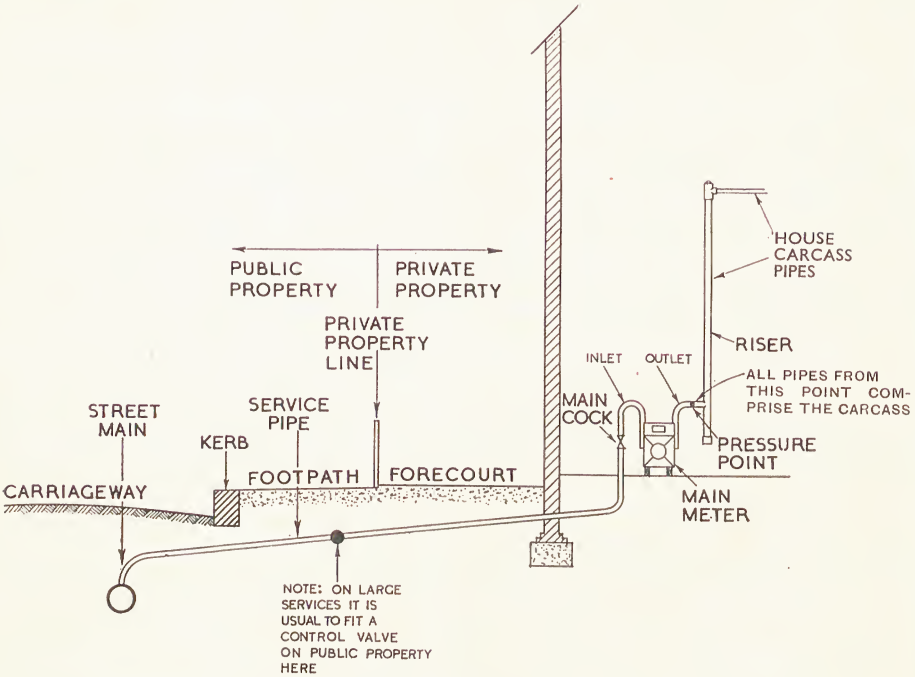


Fig. 1.—GAS SUPPLY TO A HOUSE

Diagram showing correct names of the principal parts of a gas installation.

size, but feeds into a high-to-low pressure service governor. From the low-pressure side of the governor the service pipe is taken to the meter.

Service pipes are normally taken into a building below the damp-proof course, and usually in a straight line from the main. Preparation for its reception can be made by leaving an opening just above the foundation brickwork, or by building into the brickwork a sleeve of suitable dimensions. On the high-pressure installation a safety vent in $\frac{1}{2}$-in. pipe is taken to the atmosphere just above the governor. Provision for the exit of this pipe also should be made.

The following Table gives the approximate outside diameter of service pipes.

Size of Tubing	*Outside Diameter (approx.)*
$\frac{1}{2}$ in.	$\frac{7}{8}$ in.
$\frac{3}{4}$ in.	$1\frac{1}{4}$ in.
1 in.	$1\frac{1}{2}$ in.
$1\frac{1}{4}$ in.	$1\frac{3}{4}$ in.
$1\frac{1}{2}$ in.	2 in.
2 in.	$2\frac{1}{2}$ in.

The location of the entry for the service pipe should be as near and as direct as possible to the intended position for the meter.

In blocks of flats, offices, and similar premises, the service pipe, or " riser " as it is termed, is carried vertically up the building, normally in the lift shaft or in some similar protected location. The service pipe to each meter for the separate dwellings is then taken from a tee inserted in the riser, with a double connector fitted to facilitate disconnection should any apartment be inaccessible. One main control-cock for this type of supply is fitted outside the building.

The Meter and Its Location

Modern meters, to meet domestic requirements, are very compact, and little room is required for them. Normally the corner of a cupboard provides an inconspicuous and safe position, but due regard must be given to the requirements of the meter reader. If the coal or coke cupboard is the intended location, then wall space for a bracket support is necessary. An excellent method is to provide for the meter to be fitted facing the back of an easily accessible exterior surface, and to have the index of the meter " framed " and covered by a flap or slide. Applied to the coin-slot meter, the same method would need an opening as large as the meter, to allow the coin device to be operated and enable the coin box to be extracted for emptying.

In some commercial business premises, such as retail meat and fish shops, where " washing down " is necessarily practised and brine water is used, the position of the meter must be such as to avoid all damp and exposure to the brine-water. The submission of the meter to the latter solution will very much shorten its normal life.

In industrial or other large premises the building of a special meter room is, of course, the best practice, but where not permitted the meter or meters need to be fitted where it or they will not be obtrusive, or liable to damage, and will be reasonably accessible. The very heavy work entailed for the installation of the largest meters, however, makes it desirable that the meter position should be as open as possible to facilitate the work.

The Carcass and Appliance Points

The size of pipes for the main carcass and, similarly, the size of the service pipe and the size of the meter, will depend upon the number of gas points to be provided and the total gas rate of the appliances to be installed. Theoretically, the whole installation should be adequate to pass all the gas required, without undue pressure absorption, if all the appliances were in use at one time. Such an installation is rarely found in practice, because the use of appliances is obligingly varied as to make this extreme hardly necessary.

The use of adequately sized pipes is vitally important to the successful operation of gas appliances, particularly gas fires, where the appearance of the fire in lighting soon deteriorates if a minimum pressure is not maintained at the injector. With inadequate piping, and the co-incidence of local and district peak loads occurring, results are likely to be poor.

Sizes of Pipes

Therefore, apart from co-operation with the representative of the gas undertaking, a knowledge of the normal pipe sizes needed for various appliances and, therefrom, the size of service necessary, will be of help to ensure that the requirements for the gas appliances are adequate.

In the following Table is given a list of gas rates applicable to domestic appliances. The size of pipe given should, if to pass the maximum gas rate mentioned, be limited to that indicated in the Table. Where longer supplies are needed, the next size of pipe must be used for its entire length.

TABLE I

SIZES OF PIPES REQUIRED FOR VARIOUS GAS APPLIANCES

Gas Rate (500 *B.Th.U. Gas*)	*Size of Pipe Required*	*Maximum Length to be Used*	*Appliances Concerned*
6 cu. ft./hr.	*$\frac{1}{8}$ in. ($\frac{1}{4}$ in.)	6 ft.	Refrigerators; lighting burners; gas irons; bowl fires
10–30 cu. ft./hr.	$\frac{1}{4}$ in.	20 ft.	Sink storage water heaters; low-consumption and medium-consumption circulator units; flueless heaters; portable gas fires
35–60 cu. ft./hr.	$\frac{1}{2}$ in.	30 ft.	Gas fires; small cookers; wash coppers; instantaneous sink water heaters
60–210 cu. ft./hr.	$\frac{3}{4}$ in.	40 ft.	Cookers; high-consumption circulator units and storage water heaters; geysers

Where surface work is unavoidable, $\frac{1}{8}$-in. tubing should be used for short runs and low gas rates (see *, Table). Where such supplies are to be concealed by chasing in brickwork, such pipework must never be less than $\frac{1}{4}$-in. size of tubing.

Sizes of Main Carcass Pipes

The size of the main carcass pipes will depend, of course, upon the number of appliance points they have to serve. Table II is a fair guide to the number of smaller pipes that can adequately be fed from larger sizes of pipe.

TABLE II

SIZE AND NUMBER OF SMALLER PIPES FED BY LARGER PIPE

Size of Larger Pipe	*Size and Number of Smaller Pipes that can Adequately be Supplied*			
	1¼ *in.*	1 *in.*	¾ *in.*	½ *in.*
1½ in. . . .	2	3	6	15
1¼ in. . . .	—	2	4	10
1 in. . . .	—	—	2	5
¾ in. . . .	—	—	—	3

Sizes of Service Pipes

The service pipe and the lead to the carcass from the meter must, of course, be large enough to carry the maximum demand of the whole installation. The following tabulation of the maximum carrying capacities of various sizes of service pipe of different lengths will also help to gauge the sufficiency of the gas installation.

TABLE III

MAXIMUM CAPACITY OF VARIOUS SIZES OF SERVICE PIPES OF DIFFERENT LENGTHS

Length of Service	*Size of Service and Maximum Carrying Capacity*		
	1 *in.*	1¼ *in.*	1½ *in.*
30 ft. . . .	200	400	700
50 ft. . . .	140	300	470
100 ft. . . .	—	200	320

Appliance Points

From the framework of the carcass, supplies are taken to as near the intended location for the appliances as possible. These supplies should be run when the rafters are in place, before the flooring is laid, and the size of the supplies should be no less than ½-in. tubing for any point. As far as possible, the piping should be fitted parallel with the joists, to avoid

cutting them, but in circumstances where crossing the rafters is unavoidable, the recess that is made to carry the supply pipes should only be sufficient to lower the pipe to the level of the top of the rafters, and should be cut as close to the support of the rafters as is practicable. For any wall points which are planned, and need tubing larger than the $\frac{1}{4}$-in. size, the chasing of the brickwork up to the position of the point is desirable, to assure that the supply, when installed, will be adequately covered in the plastering.

At this time, previous to the arrival of the tradesmen to do the interior work, the ability to give the position of the respective appliance points to the gas-fitter to enable him to complete his installation work is a tremendous advantage. It will save a great deal of time and labour, and prevent the otherwise unavoidable spoiling of finished work, the refitting and refinishing of which means additional expense.

Testing Pipework for Soundness

As the installation of the pipework for the carcass proceeds, it is essential that it is tested for soundness before any part of it is enclosed by further progress of work. On domestic installations it is quite possible to get the entire carcass installed and then tested in one operation, without delaying the progress on the building. On larger installations, however, this is not practicable, and the sections of the carcass must be tested as soon as they are completed, to permit other work to proceed without delay.

After connecting up the various sections and so completing the carcassing of the building, the entire work should then be tested.

Methods of Testing for Soundness

One method of testing for soundness is by meter test. This method is to charge the carcass or carcass sections with gas, and then to note any movement by the test hand of the meter. This method is somewhat lengthy if a satisfying test is to be made. Weeps of gas are the most insidious type of leak, the most aggravating, and the most difficult to locate once the pipework is enclosed. Therefore, if the meter test is curtailed or the meter happens not to register very small quantities, leaks of a minute nature can quite possibly be overlooked at the critical time.

Compared with the inadequacy and delay of the meter test for soundness, the instantaneous and infallible method with the use of the simple U-tube pressure gauge carries all advantage. Using the U-tube pressure gauge, tests can be carried out with compressed air before gas is available ; the air pressure used is much greater than the normal gas pressure, thereby providing a high safety factor ; finally, the U-gauge will noticeably indicate the most minute of leakages in less than 5 minutes.

Testing by U-tube Pressure Gauge

All points on the carcass or carcass section are capped off, with the exception of any one convenient point which will be used for the attachment of the testing tee. The testing tee is made up as shown in the illustration in Fig. 2. The tee-piece is attached to the open point, the U-gauge is connected to the centre outlet of the tee, and the nosepiece and control-cock are used to charge and seal the pipework with compressed air.

According to the normal gas pressure provided in the locality, the carcass should be charged to at least double the likely maximum pressure. When this pressure is reached, as indicated on the U-gauge, the control-cock is turned off to seal the charge. From the moment of sealing the carcass, if the pipework is unsound, the gauge medium will begin to fall. A leak of small size will cause it to fall to zero instantly—a weep of gas will be indicated by a gradual lowering of the pressure in the carcass. But, for any test, the time for which the gauge pressure is permitted to stand need never be longer than 5 minutes. If after this time no fall of the gauge medium occurs, then the pipework may be passed confidently as being gas-tight.

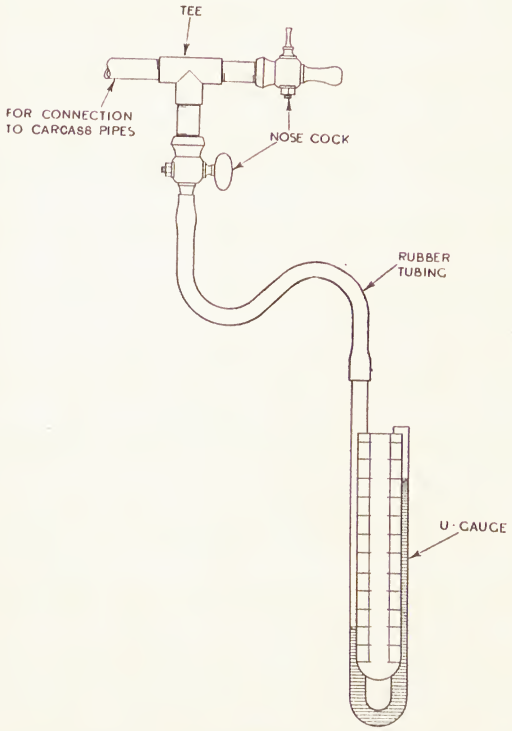


Fig. 2.—Method of using U-gauge for testing gas carcasses for soundness

Air is admitted to the top cock which is then closed. The cock to the gauge is left open. Any escape is indicated by a lowering of the water level in the right-hand limb of the gauge.

Locating Leakages

For the location of leakages in carcass work several methods are practised.

(1) By U-gauge—comparative pressure loss with gas on.

(2) By smell after charging with gas.

(3) With the use of a soap-and-water solution, after charging with air or gas.

(4) By smell after charging with acetylene gas.

Of these methods, for open carcass work, the last is the quickest and

the surest, the very pungent odour of the acetylene gas quickly being noticeable locally at the point of leakage. (A refinement to find the exact place of leakage is to use, in conjunction with the acetylene, a soap-and-water solution for brushing over the faulty pipe or joint.) For this method of test small cylinders of compressed acetylene gas are obtainable, each cylinder being charged with sufficient gas to serve for testing all carcasses of a small estate of houses.

LOCAL FITTING FOR APPLIANCE POINTS

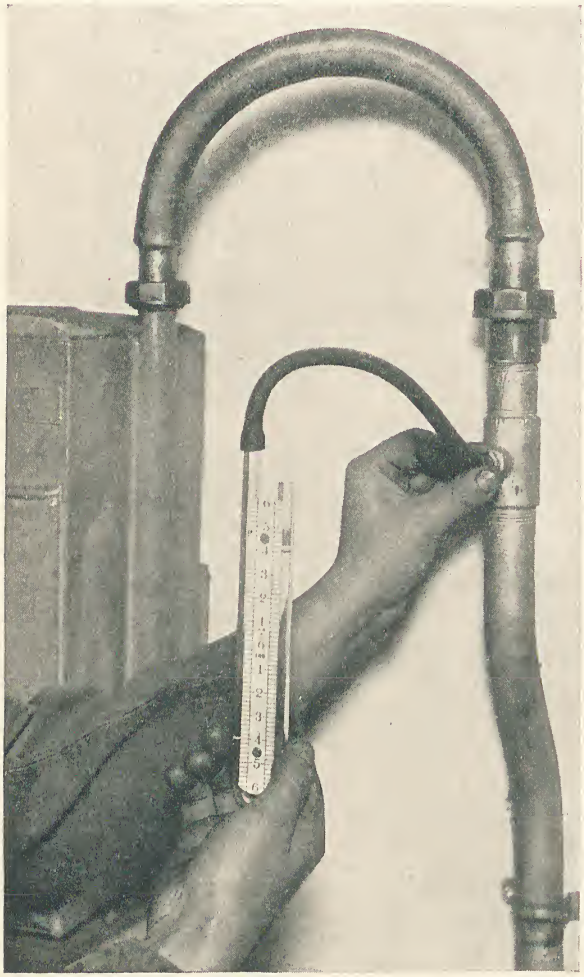


Fig. 3.—Using a U-tube pressure gauge to take the pressure at the outlet of a meter.

Gas Fires—Hearth Type

Before filling in the cradle of the hearth a concealed supply for the gas fire can be laid and then be embedded in the concrete filling. The tubing for this supply need be only $\frac{1}{4}$-in. size. The inlet end should terminate just beyond the trimmer joist, usually on the right of the hearth, in line with the carcass point, with sufficient space between the ends for the insertion of a union control-cock. The outlet end should stand just proud of the hearth level at the centre back of the fireplace. Both ends must be left capped until the appliance is installed and the union-cock fitted. Centrally above the union control-cock is fitted a hinged floor-plate to provide immediate access to the cock. Where any other than plain boarding is used for flooring it will

be necessary to provide a floor box to enclose the cock.

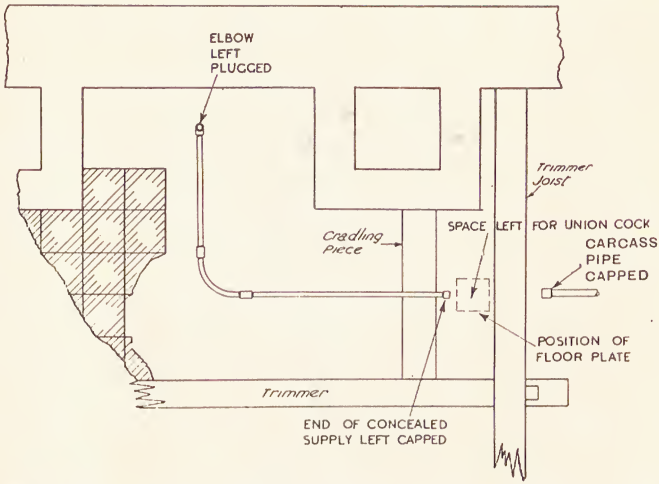


Fig. 4.—METHOD OF RUNNING CONCEALED GAS SUPPLY TO A HEARTH-TYPE GAS FIRE

The pipe is laid before the hearth is concreted. The pipes can be connected subsequently if a gas fire is required.

Coke Fires—Gas-lighted

Coke fires incorporating a gas burner for ignition are now a common medium for heating. But although positioned similarly to the hearth-type gas fire, the building-in requirements of this type of fire exclude the adoption of the method of concealing the supply as outlined for the hearth gas fire. As far as the gas-fitter need run his supply is to a capped point in the hearth, as close to the fire as possible.

From this point the connection is made to the burner of the fire by brass tubing over the surface of the hearth. This connection includes a special control-cock having an adjustable restrictor, for the regulation of the gas rate to the gas burner of the fire. Standard practice is also to include a flex connector in this connecting hearth supply, to permit a portable gas fire to be used for short-period heating, or for use during the indefinite period of the change of seasons.

Gas Fires—Panel Type

Depending upon the particular make of panel fire unit selected, the necessary opening for the reception of the fire will be provided in the construction of the building. The dimensions of the opening required will be provided with the fire. Normally, the base of cavity is about 1 ft. 6 in. above floor level.

To keep the unit rigidly in position, all panel fires have a complementary retaining bar built across the opening, to which the fire is attached. The location of the fixing bar is given in detail on instruction cards issued with panel fires by all makers. The fixing of this bar in the course of construction of the opening is an advantage.

The position for the gas supply-point for the fire can be on either side or in the centre of the base of the opening. Preferably this supply should

Fig. 5.—CONNECTING UP THE GAS SUPPLY TO A PANEL FIRE

be brought up from the floor, where it is then possible to fit a control-cock into the supply under the boards and to be concealed under a hinged floor-plate.

Portable Gas Fires

Provision for the use of portable gas fires is made by the installation of flex socket-points in suitable positions. (See Plug-in Points.)

Water Heaters—High-consumption Types

To facilitate the ventilation of high-consumption water heaters, multipoint and bath-type instantaneous heaters, circulator units and storage heaters, the position appointed for their installation should, wherever possible, be against or near to an outside wall. It will then be practicable to have an opening provided in the brickwork, commensurate with the intended position of the heater and as high as possible, for the flue-pipe from the heater to be taken to the outside. The normal range of flue-pipe sizes necessary for high-consumption water heaters is from 3 in. to 5 in. Asbestone flue-pipe is always used for outside flue-pipe installations, and the external diameter is greater than its nominal size by a maximum of ½ in. If an opening for the exit of flue-pipe is to be left, in preparation for the installation of any water heater, its diameter should be greater than the nominal size of the flue-pipe to be fitted by a minimum of 1 in.

Venting Water Heaters into Solid-fuel Fire Flues

The venting of water heaters into solid-fuel fire flues should be avoided, owing to the deleterious effect of condensation which may be formed on the interior of the flue. This objection is particularly important with regard to " Economy " flues. Although this type of flue is entirely satisfactory for gas fires which are virtually free from condensation troubles, the high porosity of the material of which the flue blocks are made, and the narrow section of the walls of the blocks, make it inadvisable to recommend them for the ventilation of water heaters of any type.

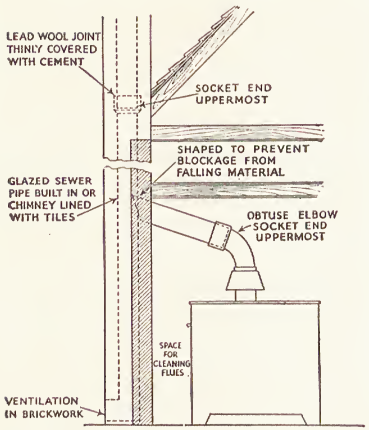


Fig. 6.—METHOD OF GAS-BOILER FLUE CONNECTION TO EXISTING CHIMNEY

It is a wise precaution to line chimney with glazed tiles or glazed sewer pipe, the joints being proof against condensate. With an ordinary chimney, condensate may seep through the walls.

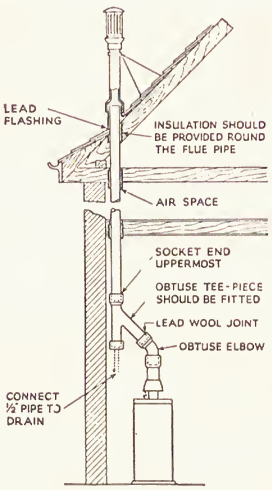


Fig. 6A.—GAS-BOILER FLUE — ASBESTOS CEMENT PIPE, TERMINATING ABOVE ROOF

Note the offset and drain point.

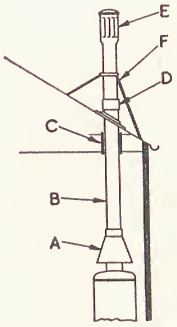


Fig. 7.—FLUE FROM INSTANTANEOUS GAS WATER HEATER TAKEN STRAIGHT UP THROUGH ROOF

A, baffler. B, secondary flue. C, protective insulation. D, waterproof flashing. E, terminal. F, supporting strap.

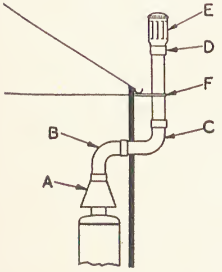


Fig. 8.—FLUE TAKEN THROUGH WALL TO EXPOSED POSITION

A, baffler. B, bend. C, outside flue, sockets looking down. D, terminal. E, louvres in terminal exposed to wind. F, supporting stay.

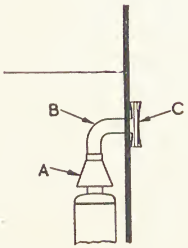


Fig. 9.—DISCHARGING FLUE TO WALL TERMINAL

Showing the use of a "Ventile" on the wall. A is the baffler. B, bend. C, "Ventile."

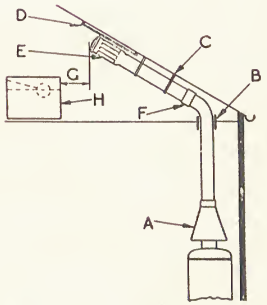


Fig. 10.—DISCHARGING FUEL INTO VENTILATED ROOF SPACE

A, baffler. B, insulated sleeve. C, strap. D, insulating sheet. E, terminal. F, socket, looking down.

Gas Supplies to Water Heaters

Storage heaters, circulator units, and wash boilers have their gas connections and controls within a short distance from the floor, and all that

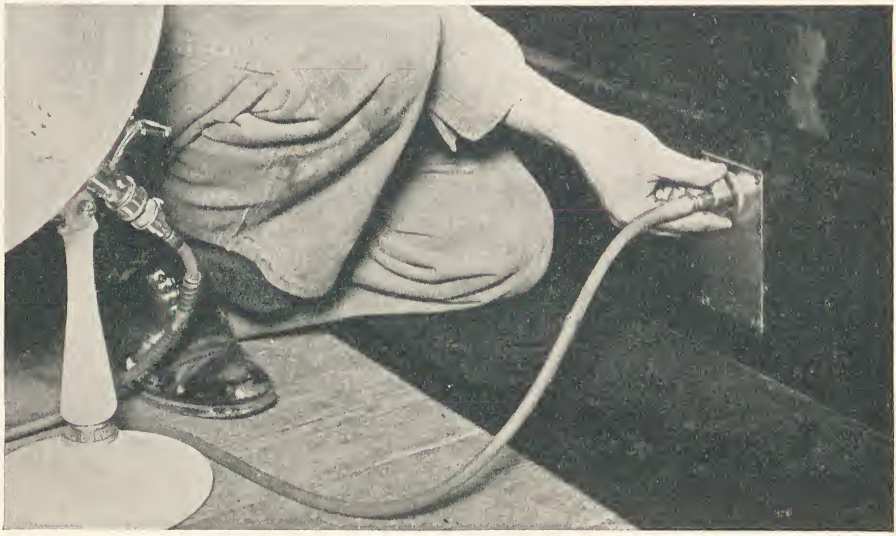


Fig. 11.—A SKIRTING-BOARD PLUG-IN GAS POINT

is needed is a capped point protruding above floor level and just clear of the skirting board behind the appliance.

Water heaters such as bath and multi-point geysers, which are fixed to walls, should have the gas supply ($\frac{3}{4}$ in.) chased into the brickwork and terminated with a plugged elbow looking forward at about 3 ft. above floor level, immediately below where the heater is to be installed.

For sink water heaters the gas supply should be a capped floor point situated on either side of the sink.

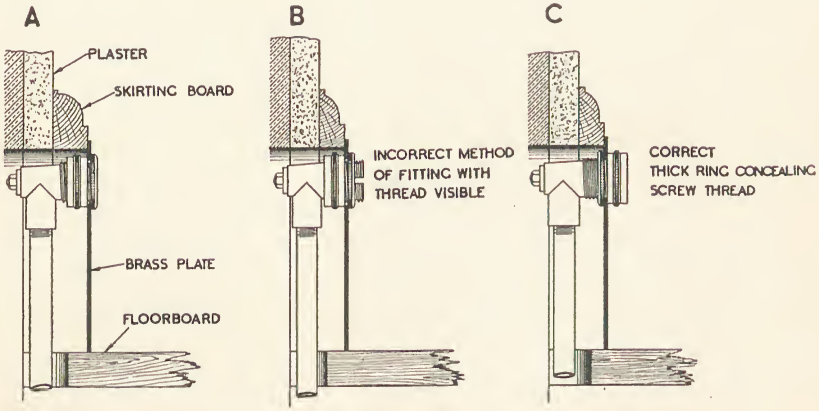


Fig. 12.—METHOD OF SECURING FRONT PLATE TO FLUSH-FITTING SOCKET ON SKIRTING BOARD

Other Appliance Points

Cookers, refrigerators, drying cabinets, and flueless heaters are appliances which require only a capped floor point in the vicinity of their proposed position.

Lighting Points

Domestic lighting is provided by ceiling pendants, wall brackets, floor standards, and table standards. The two last units are portable with flexible tube connections for connecting into plug-in gas points (see Plug-in Points).

The supply for the wall-bracket point is run in $\frac{1}{4}$-in. tubing on the face of the brick wall, and terminates, normally about 6 ft. above the floor level, with a plugged elbow looking forward, which projects sufficiently to protrude after plastering is done.

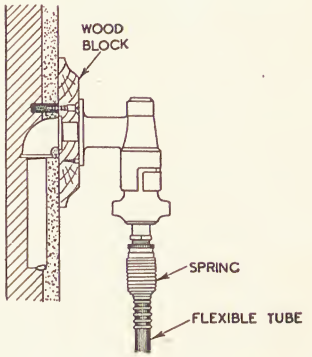


Fig. 13.—CORRECT METHOD OF ATTACHING NO. 2 TYPE OF PLUG AND SOCKET GAS CONNECTOR TO WALL

Note how elbow on gas supply is fitted so as to come just forward of the face of the wall.

The ceiling supply for the pendant is run between rafters of the ceiling to the position for the pendant point, and terminates with an elbow or tee looking downwards immediately above the position of the pendant point. A capped stem of tubing is temporarily inserted into the elbow or tee until after the work on the ceiling is completed and the pendant fitting is to be installed. It is essential that this ceiling supply be supported by a cross-batten between the rafters at the elbow or tee, to take safely the weight of the pendant and its complementary fittings.

Plug-in Points

Portable gas appliances and domestic gas equipment, to which the plug-in connector fitting is complementary, are portable gas fires and bowl heaters, gas irons, gas pokers, ring burners, lamp standards, table standards, curling-iron heaters, toasters, etc., and, therefore, the manifold uses for which the plug-in connector can be used warrants the inclusion of at least one of this fitting in every room. There are four varieties of the fitting, to cope with all situations. The plug and socket of all types are made to British standard specification, and are perfectly interchangeable, while either can be obtained separately.

Types of Plug-in Connector Fitting

Type 1.—This pattern of the flex-cock has a male thread for connection to the end of a pipe-run, but is particularly favoured for fitting on the floats of cookers for the use of portable equipment in the kitchen.

Types 2 *and* 3.—These two types of flex-cock serve an exactly similar purpose, but Type 3 has an additional control-tap incorporated. A

flange-plate is included in the design for floor or wall fixing, the supply for the latter method being the same as outlined for the wall-bracket lighting point.

Type 4.—This pattern is the concealed type of flex-cock, and is the neatest method of providing individual plug-in points. The socket is fitted behind the skirting board and the opening covered by a front plate fitted flush with the face of the skirting board. The complete fitting comprises socket, plug, and face plate.

Type 5.—This flex-cock is the type for inserting in a run of pipe, and has a male and a female thread to facilitate this purpose. It is the pattern referred to in the section on Gas-ignited Coke Fires. This pattern of the plug-in connector fitting is the type that should be used for floor points when required, and concealed under a floor plate.

QUESTIONS AND ANSWERS

What are the Sections of a Gas Installation for a building, commencing from the distributing main ?

(1) The service pipe.
(2) The meter.
(3) The carcass.
(4) The appliance points.

How is the Service Pipe arranged on a Low-pressure System ?

It is taken direct from the main to the control-cock before the meter, with a slope back to the main for the return of condensation. If a locality necessitates any incline of the service away from the main, and dehydration is not practised by the undertaking, a siphon is inserted at the lowest point.

How is the Gas distributed from the main on a High-pressure System ?

The service pipe feeds into a high-to-low pressure service governor. From the low-pressure side of the governor, the service pipe is taken to the meter.

What measures are taken when building to receive the Service Pipe ?

Service pipes are normally taken into a building below the damp-proof course, and preparations for their reception can be made by leaving an opening just above the foundation brickwork, or by building into the brickwork a sleeve of suitable dimensions. On a high-pressure installation, a

safety vent in $\frac{1}{2}$-in. pipe is taken to the atmosphere just above the governor. Provision for the exit of this pipe should also be made. The location of the entry for the service pipe should be as near and as direct as possible to the intended position for the meter.

What considerations should be borne in mind when installing the Supply Pipes?

As far as possible the piping should be fitted parallel with the joists, but where it has to cross them, the recess made should not be deeper than necessary and should be cut as close to the support of the joist as is practicable.

For wall points, with tubing larger than $\frac{1}{4}$-in. size, the chasing of the brickwork up to the position of the point is desirable, to ensure that the pipe, when installed, will be adequately covered in the plastering.

What Methods are available for Testing the Soundness of sections of Gas Piping?

(1) By charging the carcass or carcass sections with gas and then to note any movement by the test hand of the meter.

(2) By the use of the U-tube pressure gauge.

What are the Objections to the Meter Test for soundness?

(1) This method is somewhat lengthy if a satisfying test is to be made. If the test is curtailed, or the meter happens not to register very small quantities, leaks of a minute nature, which will be difficult to locate after the pipework is enclosed, can quite possibly be overlooked.

(2) Gas must already be laid on.

Compared with the meter test, what are the Advantages of the U-tube Pressure-gauge Method of Testing?

(1) Tests can be carried out with compressed air before gas is available.

(2) The air pressure used is much greater than the normal gas pressure, thereby providing a high safety factor.

(3) The U-gauge will noticeably indicate the most minute of leakages in less than five minutes.

What Air Pressure should be used in the U-gauge Method of Testing for soundness?

The carcass should be charged to at least double the likely maximum gas pressure. For house carcasses and other small, low-pressure installations, a pressure of 6-in. water column allows a safe margin.

How is the Pipe Charged with Compressed Air ?

Air is admitted by means of a cock on the testing tee, which also carries the U-tube gauge. The quantity of air required to raise a test pressure of 6-in. water gauge in a house carcass is so small that the desired compression can easily be obtained by blowing with the mouth until the gauge registers the correct pressure. Larger carcasses or those requiring to be tested at a higher pressure may be pumped by means of a bicycle pump. The testing of very large installations may necessitate the use of a compressor.

How may Leakages in Carcass Work be located ?

(1) By U-gauge comparative pressure loss tests with gas on.
(2) By smell after charging with gas.
(3) With the use of soap-and-water solution, after charging with air or gas.
(4) By smell after charging with acetylene gas.

Which of the above Methods is the Quickest and Surest ?

By smell after charging with acetylene gas. The pungent odour of the acetylene gas is quickly noticeable locally at the point of leakage. The exact place of leakage may be discovered by brushing a soap-and-water solution over the faulty pipe or joint.

THE DRAINAGE OF BUILDINGS

PART IV.—IRON-PIPE DRAINAGE

OF recent years there has been a growing tendency to use coated cast-iron pipes for drainage purposes. Their use is approved by the Ministry of Health, and special attention is given to iron drainage in the by-laws of the London County Council. Coated cast iron is used not only for the drain pipes, but also for the manholes, gullies, interceptors, and other fittings pertaining to drainage work, so that a complete system of cast-iron drainage is possible for any building. The pipes and fittings have a long life, and it is only in cases where strong acids are discharged into the drain that they are liable to any serious corrosion. It is necessary that the pipes should be of water-main quality, and that they should be properly coated with Dr. Angus Smith's solution.

Cast-iron Pipes and Fittings

In the schedule which is attached to the by-laws of the London County Council, it is specified that 4-in. pipes, including the socket and spigot, shall not weigh less than 157 lb. per 9-ft. length, and that the thickness of metal for pipes, traps, and fittings shall not be less than $\frac{3}{8}$ in., that the caulking space in the sockets shall not be less than $\frac{5}{16}$ in., nor the depth of the socket less than 3 in. Similarly, 5-in. pipes must weigh 186 lb. per 9-ft. length, 6-in. pipes 225 lb., 7-in. pipes 316 lb., 8-in. 370 lb., and 9-in. 441 lb., per 9-ft. length. It is well to note that such pipes may be obtained in lengths ranging from 12 ft. to 9 in., as may be seen in the makers' catalogues ; lengths of 9 in., 12 in., 15 in., 18 in., 21 in., 2 ft., 3 ft., 4 ft., and 6 ft. are available. Bends of all sizes may be obtained ; also elbow bends and knuckle bends, including those which form special reducing pipes, are made in short lengths; also special drain chutes: these are short pipes having enlarged mouths, for use on pipes at manholes to facilitate cleaning and flushing (see Fig. 1A).

The joints of iron drains are usually made with caulked blue lead and gasket or lead rope ; the gasket or lead rope is first caulked into the socket, which is afterwards filled with molten lead and well caulked. Joints can also be made with lead wool alone or with lead wool and gasket ; in any case, it is most important that the material should be thoroughly caulked. Leaky joints are invariably due to improper filling and caulking.

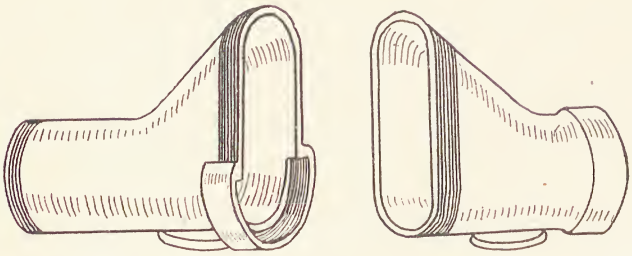


Fig. 1A.—SPECIAL DRAIN CHUTES
The mouth is shaped to facilitate cleaning and flushing.

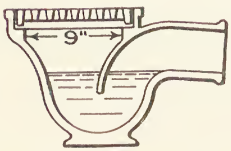


Fig. 1B.—COMBINED GULLY AND TRAP

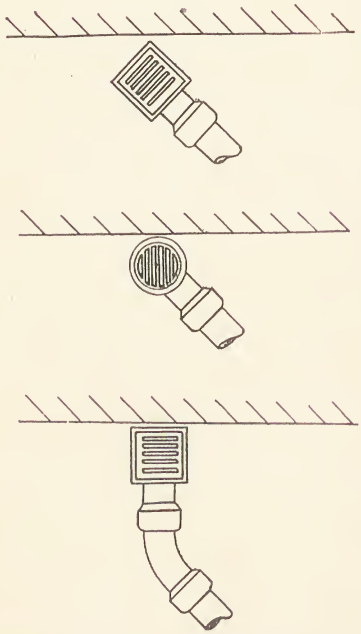


Fig. 2.—IF GULLY TOP AND TRAP ARE SEPARATE, IT ALLOWS TOP TO BE SELECTED OF A SHAPE TO FIT IN WITH THE POSITION

Gullies

It is very important that anyone designing a drainage system should have a thorough knowledge of the various fittings which are available, and for this purpose it is well to study makers' lists, in which illustrations are given of a very large number of fittings suitable for different purposes. There may be great waste of labour and also of material where an attempt is made to use an unsuitable fitting in any particular position. The work will present a better appearance, and will be more satisfactory in character and in use, where unnecessary complications are avoided.

The following examples will serve to show the type of the goods which can be obtained, but are in no way inclusive; Fig. 1B shows a simple gully and trap combined. It is, however, more convenient to have a trap and gully top in two separate pieces; if the gully top is circular in plan, it can be placed in any position, whereas if a square gully top is obtained, and the gully and trap are in one piece, the appearance may be awkward if it does not happen to come at right angles to the building near which it is placed. Fig. 2 shows the two possibilities.

Flushing Gully

The traps are made of various sizes and with the outgo pipe at different angles, as shown in Fig. 3; and the water area in the trap can be larger in one case than in another in accordance with requirements. These requirements will depend upon the nature of the waste entering the gully. For example, in Fig. 4 a flushing gully is shown; such a gully is used where large

quantities of grease are received from scullery sink waste pipes. The waste-pipe connections are shown at the lower level, and the flushing pipe at the top. An automatic flushing cistern holding, say, 40 gal., discharges water *via* this pipe to the rim space, from which it is discharged round the circumference of the upper part of the gully. This gully requires a large water area, grease collects on the surface of the water and congeals and, when the circumferential flush, which comes down with some force, takes place, the grease is broken up and is discharged through the gully into the drain. The joints between the trap and the lengthening piece through which the waste pipes discharge, and between this lengthening piece and the gully top, are made with caulked blue lead or with Portland cement.

The diagram A in Fig. 5 shows a plain gully top without inlets, which would be fixed above a trap such as is shown in Fig. 3. The depth of the trap can be increased to any degree required by the use of a lengthening piece, such as is shown in diagram B, Fig. 5.

In Fig. 6 two forms of gully tops are shown. Raising-pieces can be obtained having inlets of various sizes, and they are particularly useful for the reception of rain-water branch drains.

In Fig. 7 certain gully tops are shown in plan, having side connections for waste pipes. Where the gully top has to receive a down pipe, or a pipe coming in at an angle, patterns similar to those shown in Fig. 8 can be obtained.

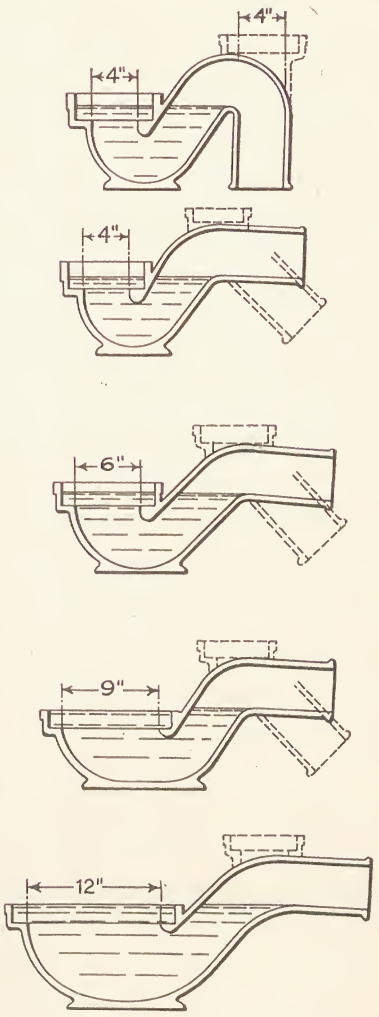


Fig. 3.—GULLY TRAP BOTTOMS CAN BE OBTAINED WITH OUTGOES AT VARIOUS ANGLES

Yard Gullies

In Fig. 9A is shown a deep yard gully which is suitable for the reception of surface water. It has a deep receptacle in which grit, which would otherwise tend to block the drain, is intercepted. Such gullies must be

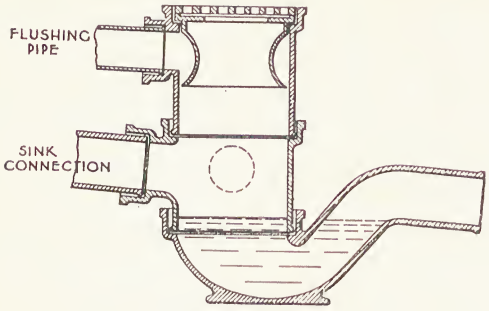


Fig. 4.—FLUSHING GULLY

This gully is particularly useful for the reception of sink wastes.

cleaned out as the silt accumulates, and for this reason it will be observed that there is a special movable bucket, with a handle, in the gully shown in Fig. 9B, by means of which the grit can be more easily removed.

In Fig. 10 is shown a gully having a trap with a deep seal, which is used for the purpose of intercepting oil or petrol at a small garage. This gully is also provided with a deep bucket for the removal of silt, but the essential feature is the deep seal of the trap by means of which a moderate amount of oil or petrol may be prevented from passing through to the drain. If necessary, the outgo drain can be provided with a cleaning-eye. This would be suitable for only a very small garage. Where several cars are kept, a special petrol interceptor, described below, is required.

In Fig. 11 a trapless gully is shown, such as is used on a rain-water drain. It should be noted that such a trap can be used only on drains which do not contain sewage, and which are properly intercepted from sewage drains.

Petrol Interceptors

The intercepting tanks, which are required under the regulations of the London County Council, for motor garages are very important. Special iron bends and dipping pipes can be obtained which are useful in the construction of such tanks. In Fig. 12 a design is given for a petrol interceptor suitable for a garage of six cars. It is constructed of brickwork and concrete in three divisions, having a concrete roof reinforced with steel joists. Each division is 3 ft. wide by 3 ft. deep by 3 ft. long. The drain enters in the position shown, and three dipping pipes are fixed at the same level. In the first division the dipping pipe allows more space for the accumula-

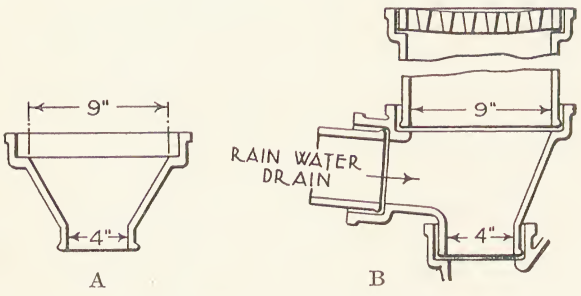


Fig. 5.—TYPICAL GULLY TOPS

A, gully top without inlets. B, gully top with inlet and raising-piece, suitable for rain-water drain connection.

tion of grit than is the case in the succeeding divisions, grit from the gully inlet drain running to the interceptor is washed into the pit. Three divisions are provided in order to prevent any petrol that may be spilled inadvertently from short circuiting to the outlet: petrol, being lighter than water, floats. Each division of this tank is rendered with cement mortar so as to be watertight. A manhole opening and cover are provided to each division, so that there may be free access for cleaning and inspection, also a vent pipe is carried up from each division and is connected to a main vent pipe. It should be remembered that petrol vapour is inflammable, and that the vent pipe must, therefore, be taken to a safe place.

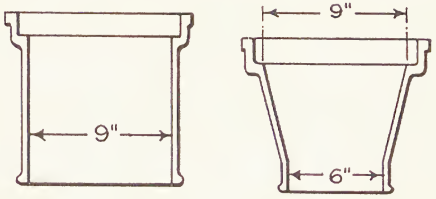


Fig. 6.—TYPICAL GULLY TOPS

A, raising-piece or gully top for 9-in. trap. B, gully top for 6-in. trap.

USES OF IRON DRAINS

Iron drains may occur on any system. As already stated, they are often laid where the pipe passes under or through a building, although stoneware drains may also be laid in buildings if proper precautions are taken. Speaking generally, however, it will be found to be more convenient to use iron pipes in such places, if only for the reason that the work may be carried out with greater rapidity. If the pipes come above basement-floor level, and have to be supported on piers or brackets, it is evident that iron pipes will be required. It will often be found more economical to lay iron pipes than to use stoneware in general work, for although the material is dearer, the cost of labour—taking into account trenches, laying and jointing, and concreting—will be less, and the time that is lost in waiting for cement joints to set, or for repairing those which fail under test, will be saved.

The Use of Special Fittings in Cast-iron Drainage

Seeing that manholes, gullies, and connections of cast iron are available, it becomes possible to design the most complicated arrangement of drains, and to obtain the pipes and fittings of the exact lengths and dimensions required, so that these may be delivered on the works ready for installation, just as the parts of a complicated machine may be marked and numbered and sent abroad for erection, with the necessary blue prints for the instruction of the man who has to erect them. Iron pipes can also be cut to lengths as required.

Fig. 13 shows a plan prepared for a part of a drainage system serving a range of w.c.s and a bath-waste gully. An accurate plan having been prepared, showing the space available in the building and the thickness of the walls and so forth, the various fittings were marked in

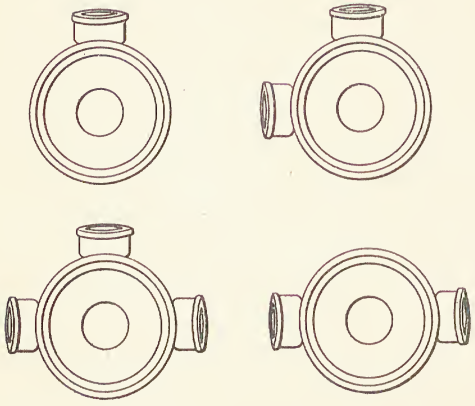


Fig. 7.—PLANS OF GULLY TOPS

Showing the various inlets, which may be from 2 in. to 4 in. in diameter.

position on the plan, and the exact lengths of the pipes, branches, special cast-iron socket pipes for connection to the w.c. outlets, the manholes occurring at the points B and C, the connections to the vent pipe and to the gully, together with the gully connection to the bath-waste pipe, were all carefully drawn out, and the goods were obtained from the manufacturers. These goods were then marked and numbered and shipped to a contractor abroad, who had not the slightest difficulty in fixing them in position in accordance with the drawing and specification prepared. The saving of trouble and consequent saving of expense were considerable, and the work when finished was necessarily in exact accordance with the design. With the general drawing and specification, a separate list was handed to the contractor in which the various fittings and pipes were carefully described. Such work cannot be done in any haphazard manner. In the case described, the gullies and fittings, etc., were inspected at the maker's shop, and were fitted together loosely for trial and then marked. An example of the marking, and of the items in the list which was prepared for all fittings on this work, is given below.

FITTINGS MARKED NO. 8

Inspection chamber No. 1/24 D, 4-in. diameter, 135° branches.
Short bend No. 12, 165°, 4-in. diameter.
Long bend No. 18, 135°, 4-in. diameter.
Short bend No. 12, 165°, 4-in. diameter.
6-in. to 4-in. taper No. 1, socket on small end.

Fig. 8A.—GULLY TOP WITH OBLIQUE BRANCH 2-IN. TO 4-IN. DIAMETER

Fig. 8B.—GULLY TOP WITH VERTICAL BRANCH 2-IN. TO 4-IN. DIAMETER

The explanation of the list is as follows: All fittings to be fixed at this point were marked No. 8, and the place where they were to be fixed was similarly indicated in the plan. Inspection chamber No. 1/24 D was shown in the maker's catalogue numbered in this manner. It is shown in Fig. 14 diagrammatically, together with the other fittings. The contractor had a copy of the catalogue so that he could easily identify the

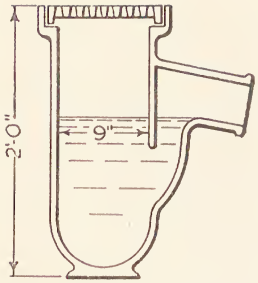


Fig. 9A.—YARD GULLY WITH SILT TRAP

items. The short bends No. 12 were very flat bends, shown in the catalogue so numbered, the angle of the bend being 165° (see Fig. 15). The long bend was similarly described, and also the taper piece.

Another example is as follows :—

FITTINGS MARKED H

Gully No. 52, 4-in. by 3-in. inlet with galvanised grid to fit.

Trap No. 59, 4-in. diameter, 95° outlet (see Fig. 16).

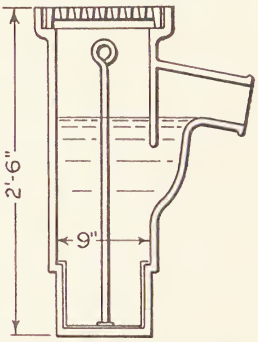


Fig. 9B.—YARD GULLY WITH SILT TRAP

This has a movable lifting bucket used for removal of silt.

Gully 52 was indicated by this number in the catalogue ; it had a 4-in. outlet and a 3-in. side inlet and a 4-in. trap. The gully top was separate from the trap, and the outlet was at the angle stated.

It is not difficult to select and arrange fittings in this manner—each having its special mark affixed in white paint, and its position being indicated clearly on the plan. It is then a very simple matter to place things in position.

THE SPECIFICATION FOR IRON DRAINAGE

The following specification is of general application, but certain facts such as the existence of old drains have been assumed.

(1) The new system will consist throughout of iron drains as specified in detail below. All gullies will be of iron, also all connections for vent pipes or soil pipes. Shallow manholes (that is to say, manholes in which the drains can easily be cleaned by means of rods used from the surface of the ground) will be made of cast iron, where junctions occur. Similarly, where changes of direction or of gradient take place, the main drains and any branch drains will be connected to a small cast-iron inspection chamber or hatch-box. These hatch-boxes are cast-iron pipe bends or branch pipes having recessed covers secured with gun-metal bolts and nuts, with watertight washers, and are to be obtained from Messrs. . . ., whose catalogue is attached. They can be used for all manholes up to a depth of 3 ft. or less, but in cases where many junctions occur, and where it is not possible to obtain a cast-iron manhole that will meet the requirements of the case, a brickwork, concrete, or masonry manhole must be made in accordance with the description given later in this specification.

For manholes which are of greater depth than 3 ft., brickwork, masonry, or concrete manholes must be constructed.

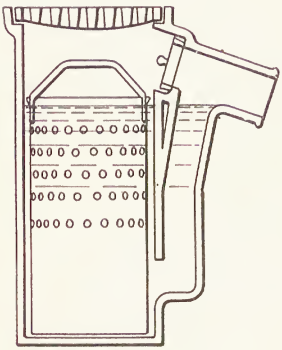


Fig. 10.—DEEP-SEAL YARD GULLY FOR INTERCEPTING PETROL AND OIL, WITH PERFORATED BUCKET FOR CATCHING GRIT AND SLUDGE

(2) All old drains are to be taken up and removed as far as may be possible, but where this is impossible, they are to be thoroughly cleaned, and are to be filled with cream lime and sealed off at each end with a 6-in. plug of cement concrete. The drains must be absolutely filled with thick cream of lime, and it is possible that a large quantity will be required.

(3) If any contaminated earth or other foul matter is encountered in the excavation of this work, it is to be carted away at once.

Drain Construction

(4) The drains are to be laid with true grade throughout, and shall run in perfectly straight lines as shown on the plan and section. The longer lengths of drain are to be laid to their proper levels by the aid of sight-rails, which are to be fixed at the beginning and end of each trench. These sighting-rails are to be provided, fixed, and maintained by the contractor, who is to set out the positions and levels of the drains according to the drawings or in accordance with any instructions he may receive from the engineers during the progress of the work, and he is to be held responsible for the correctness of the same throughout. He is also to provide at his own cost all labour and material necessary to enable the engineers to check the levels and dimensions whenever the engineers may require him to do so. No drain is to be laid at a flatter gradient than 1 in 40.

(Although it is customary to place the responsibility for setting out work and for accurate levelling upon the contractor, this is merely a safeguard, and the engineer should give such matters his full personal attention and accept the responsibility involved.)

(5) In making the trenches, care is to be taken to remove all gravel, top soil, paving, or other material without causing unnecessary disturbance, and such material must be stored carefully for replacement.

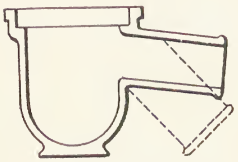


Fig. 11.—TRAPLESS GULLY SUITABLE ONLY FOR CONNECTION TO A RAIN-WATER DRAIN

(6) The sides of any deep trench must be supported with timbering as may be necessary, and the greatest care must be exercised in any case where a trench may come below the level of the footing of an adjoining wall. If necessary, close timbering is to be provided in any excavation in which the ground is unstable.

(7) If water is encountered, the contractor must provide such plant as may be necessary for its removal, and he must not allow water to accumulate in the trenches.

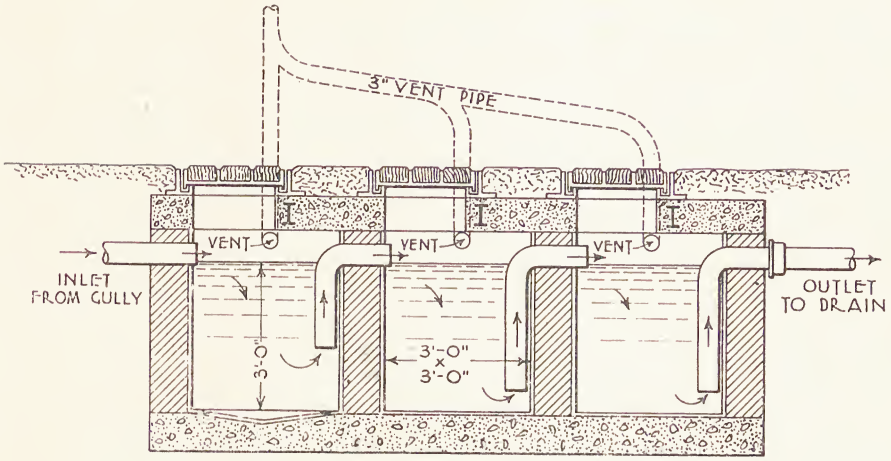


Fig. 12.—PETROL INTERCEPTOR

(8) Drains to be supported on 6-in. bed of Portland cement concrete ; where earth is unsuitable, piers of brick, concrete, or rubble must be formed and built up from firm foundation, or piles or stakes driven in ; concrete bed to be laid on planks supported by such piers or piles. Piers alone may be used where the ground is suitable. Where new drains come on the lines of old drains, old excavation, or made ground, the supporting pier must be carried down below any earth which may have been disturbed in the past. A pier as specified above is to be provided behind the socket of each pipe ; under bends at the foot of every soil pipe and vent pipe, and under every gully and rain-water shoe.

(9) Where the drains pass under the building, they are to be founded on 6 in. of concrete ; the width of the foundation is to be 18 in., and the pipes are to be bedded in and surrounded with concrete to a depth of at least 6 in. Additional support in the nature of piers must be given if the ground at the level at which the pipes are laid should prove to be unsuitable for foundations.

(This requirement for the complete encasing of the iron pipes with concrete goes beyond the requirements of most by-laws, but the practice ensures protection of the exterior of the pipes.)

(10) Long trenches are to be taken out by means of sight-rails and boning rods at exact gradients, and joint holes are to be taken out so that the barrel of the pipe may lie on a solid bed throughout its length. The joint holes must be large enough to allow a workman plenty of room for caulking the joint.

(11) The pipes are to be laid with the sockets up-hill ; and in the case of manholes in which white-glazed channels occur, the drain must be terminated in such a manner and in such a position as to receive the

invert channel exactly, and in order to obtain this result, the pipe must, if necessary, be cut as required to bring it to the right length, and at the top end must be jointed a special pipe into which a stoneware channel can fit.

(12) The drains are to be laid with an absolutely uniform fall in exactly straight lines between the manholes, or between the gullies, soil pipes, etc., and manholes. Bends will not be allowed, either upon branches or upon the main lines of the drain, unless specially ordered by the engineers, and if any such bend has to be made, owing to some special, unforeseen difficulty, special approval must be obtained and the necessary facilities must be added for cleaning purposes. Long-radius easy bends may be jointed to the hatch-boxes if necessary in order to receive the connections, but special approval must be obtained in every case.

(13) The joints are to be made as follows : The spigot must be forced well home into the socket, and must be centred so that the joint may be of even thickness all round. Tarred gasket, cold rod lead, or lead wool must then be caulked into the socket, until the socket is half full ; the joint must then be run with molten lead in sufficient quantity, so that after being caulked solid the lead forms a bevel which projects $\frac{1}{8}$ in. beyond the face of the socket against the spigot.

(14) The pipes thus laid are to be tested with water under pressure as the work proceeds, before the trenches are filled in, by inserting a plug in the lower end and filling the drain with water ; they must be made absolutely watertight. The contractor must provide all the necessary plugs, bags, or other appliances required for making water tests rapidly. A final test to be made at the completion of the work.

(15) The trenches are to be filled in, in 9-in. layers, the material being carefully rammed and watered if necessary. All surplus material is to be carted away.

Manholes

(16) Manholes occur at every change of direction or gradient, and at every point where a junction occurs ; there are to be no hidden junctions on this system. The manholes are indicated on the plan by numbers. All shallow manholes, where possible, will be cast-iron hatch-boxes, to be supplied by . . . They are to have recessed covers, secured by gun-metal bolts and nuts, with felt washers.

(17) A small brick or concrete pit is to be built for each of the cast-iron inspection chambers or hatch-boxes. These hatch-boxes and the pits which surround them are to rest upon a foundation similar to that specified below in the case of the larger manholes. The pits are to be large enough to provide comfortable access for inspection and cleaning, but are to be no larger or smaller. The walls are to be 9 in. thick, of brick in cement mortar, concrete, or rubble, which is to be neatly rendered on the inside.

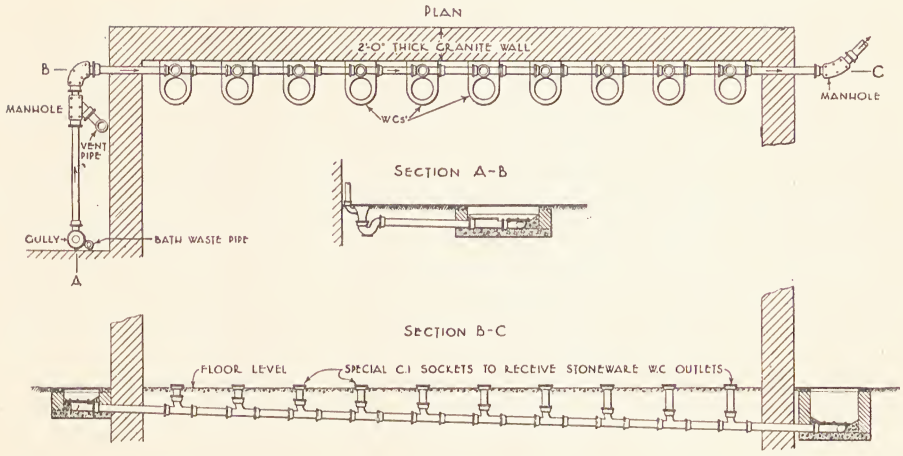


Fig. 13.—A PLAN FOR PART OF A DRAINAGE SYSTEM SERVING A RANGE OF W.C.S AND A BATH-WASTE GULLY

Note.—All pipes were obtained to exact size. The gully at point A, with special connection for a 3-in. down pipe and 90° outgo, two special hatch-box manholes for position B, and one special hatch-box manhole for point C were also obtained. The gully was marked A in white paint, the two hatch-boxes were marked B, and the other hatch-box was marked C. Thus their positions could be identified easily.

(18) The concrete floors of the manholes are to be benched up in 6 to 1 concrete, and rendered so that water in the pit may run away quickly into the drain when the hatch-box is opened.

(19) The hatch-boxes are to be absolutely watertight when the covers are bolted down on the washers.

(20) These pits are to be provided with covers similar to those specified below in the case of the larger manholes.

(21) Where hatch-boxes cannot be used, and where deep manholes occur, these are to be built in brickwork in cement, concrete, or rubble, rendered with ½ in. of cement mortar, as specified above for the shallow manholes, with the exception that if brickwork or rubble masonry is used the joints are to be raked out to a depth of ¼ in. to form a key, which must then be rendered with ½ in. of cement mortar.

(22) The interior dimensions must be not less than 4 ft. in length and 2 ft. 3 in. in breadth ; there must be ample space for cleaning and inspection purposes. The walls are to be 9 in. in thickness.

(23) The foundations are to be laid in 6 to 1 concrete 6 in. thick, and are to extend over the whole area. If the

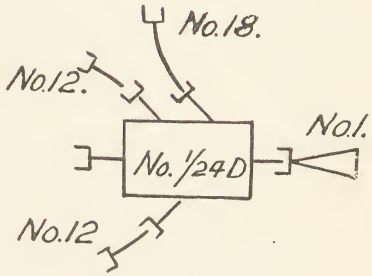


Fig. 14.—DIAGRAM OF INSPECTION CHAMBER TOGETHER WITH OTHER FITTINGS

ground upon which the manhole is to be built is unsuitable for a foundation, the foundation must be carried down in 9 to 1 concrete to such a depth as may be required.

(24) The bottoms of the main channels are to rest upon the upper surface of the concrete foundation, and are to be bedded in 6 to 1 concrete, which must be carried up vertically above the main channel to the level of the top of the main inlet pipe, from which level it is to be sloped up at an angle of 30° to form a benching, the fall being towards the channel.

(25) The channels are to be of white-glazed ware, the side channels being of three-quarter section fitting exactly on to the main channel. There must be no cutting of the side channels, and they must be of such a size and shape as to fit exactly into their positions.

(26) The inside surfaces of the manholes, including the benching, are to be rendered in 2 to 1 Portland cement mortar ½ in. thick.

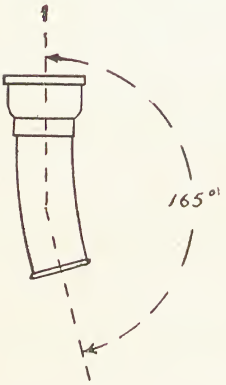


Fig. 15.—SHORT BEND

(27) The manholes when finished must be absolutely watertight up to the level of the tops of the manholes.

(28) The manholes must be partly covered with a 4-in. slab of York stone bedded in cement on the top of the wall, and the frame of the iron cover must rest on three walls and on the stone slab, and must also be bedded in cement and surrounded by concrete at the edges.

(29) Galvanised malleable-iron step irons No. . . ., as shown in Messrs. . . .'s list, are to be fixed in the deeper manholes so that there may be no difficulty of access to the interior.

General Notes

(30) The contractor must allow for placing at least one-quarter of a yard of 6 to 1 concrete round each gully, in addition to the foundation specified, and this is to be formed into a dish with a brick-on-edge kerb rendered in cement.

(31) Where lead pipes are connected to a gully, or to iron pipes, brass ferrules must be soldered to the lead pipes and a connecting joint made in caulked blue lead. Plain iron pipes must also be jointed with caulked blue lead to the gullies.

(32) The drains and manholes are to be tested as the work proceeds, and they are also to be tested at the conclusion of the work by the contractor in the presence of the engineers or their representative. In addition, the contractor must make any tests required by the sanitary inspector ; the test must include all joints and work up to the level of the gully tops. Any defects which may be discovered in the work must be made good as part of the contract, and all necessary assistance must be given by the contractor in the making of tests.

Connections to Waste and Soil Pipes

(33) All junctions between soil pipes or vent pipes and the drain are to be made with iron duck's-foot bends of water-main quality.

(34) Where the iron drains have to be connected to sanitary fittings, w.c.s, etc., inside the building, such connections must be made with special connecting pieces of cast-iron pipe having an ordinary spigot, and a socket the shape of a stoneware-pipe socket, to fit on to the pipe or earthenware outgo of the trap. The joint between the trap and the iron pipe is to be carefully made in neat cement.

(35) All waste pipes or rain-water pipes must be connected to the gullies so as to discharge below the grids, and on no account are they to be made to discharge above the grid.

(36) The contract includes the making good of all floors, walls, casings, roofs, surfaces, and pavements where disturbed, but no work of decoration is included.

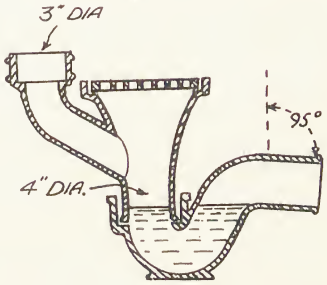


Fig. 16.—GULLY AND TRAP

Cast-iron Pipes

The cast-iron pipes for the drains shall be of the best quality, vertically cast, spigot and socket pipes, coated with Dr. Angus Smith's solution, and are to be supplied by . . . The weight of the 6-in. pipes is to be not less than 225 lb. per 9-ft. length. The weight of the 4-in. pipes is to be 157 lb. per 9-ft. length. The pipes are to be perfectly sound, truly cylindrical, perfect in form, and of the full specified diameter throughout, with a uniform thickness of metal. Any pipe which is defective will be rejected. Each pipe is to be carefully examined before it is laid.

Inspection Chambers

The cast-iron hatch-boxes for manholes are to be coated, and provided with large recessed bolted-pattern covers, fitted with gun-metal nuts, bolts, and prepared felt washers. They are to have bends and branches of the correct angles to suit their various positions. They are to be obtained from . . .

Gullies

The waste gullies are to have coated cast-iron tops, with the necessary side or back inlets of the correct sizes to suit the waste pipes, and are to be provided with galvanised grids. The gully tops are to be 9 in. in diameter, with 4-in. outlets, and are to be provided with 9-in. diameter coated cast-iron raising-pieces if necessary. The gullies are also to be provided with 4-in. diameter coated cast-iron traps, with outlets at the

required angle ; the joints are to be made in caulked blue lead. They are to be obtained from . . .

The rain-water gullies are to be exactly similar to the waste gullies specified above.

The surface-water gullies are to be Messrs. . . .'s coated cast-iron yard gulley No. 72, and are to be 2 ft. deep, with galvanised grids.

The flushing gully is to be Messrs. . . .'s coated, cast-iron, flushing-rim grease gully, with galvanised grid. It is to be provided with a coated cast-iron raising-piece of the required height, having branches of the correct size and angle for receiving the waste pipes. It is also to be provided with a coated cast-iron trap bottom with outlet at the required angle 4 in. in diameter, No. 1/3 in Messrs. . . .'s list. All joints are to be made in caulked blue lead.

Step Irons

Malleable-iron, heavy-pattern, galvanised step irons, No. 7 in Messrs. . . .'s list, are to be fixed in the deeper manholes so that there may be no difficulty of access to the interior.

Manhole Covers

Manhole covers are to be Messrs. . . .'s single sunk manhole covers, with frames having 1½-in. seals, galvanised, and the recess at the top is to be filled by the contractor with concrete, tiles, or other paving material as may be required ; for the larger manholes the opening in the clear is to be 2 ft. 1 in. by 2 ft. 1 in., but smaller sizes may be used according to instructions which will be given later in the case of some of the shallower manholes. The weight of the large covers is to be 1 cwt. 1 qr. 14 lb. The covers in all cases must be such as to allow ready access to all drains and branches.

Rain-water Shoes

Rain-water shoes, consisting of a coated cast-iron bend with a sealed inspection eye (No. 190 in Messrs. . . .'s list), must be provided at the foot of any rain-water pipe which may be connected to any gully on the drainage system where the foot of the rain-water pipe is at a greater distance than 3 ft. from the gully.

Iron-to-Stoneware Junction Pipes

The iron-to-stoneware junction pipes are to be coated cast-iron pipes or bends of short length, with a socket to take stoneware pipes Nos. 2, 5*a*, and 5*b*, as may be required, in Messrs. . . .'s catalogue, from whom they are to be obtained.

The ordinary " general conditions " would be attached to the specification.

QUESTIONS AND ANSWERS

When is a Flushing Gully employed ?

Where large quantities of grease are received from scullery sink waste pipes.

How is a Flushing Gully constructed, and how does it operate ?

The waste-pipe connection enters just above the trap, and the flushing pipe enters at the top. The automatic flushing cistern discharges the flushing water into this pipe. The water is projected round a rim, and is discharged round the circumference of the upper part of the gully. As the flush comes down with some force, it breaks the congealed grease surface of the water in the gully and discharges it through the gully into the drain.

How is a deep Yard Gully for the reception of Surface Water constructed ?

With a deep receptacle in which grit, which would otherwise tend to block the drain, is intercepted.

What is the essential feature of a Yard Gully for intercepting Oil or Petrol ?

A deep seal for the trap, by means of which oil or petrol may be prevented from passing through to the drain, as the petrol, being lighter than water, floats on top.

How may a Petrol-intercepting Tank be constructed, using special iron bends and dipping pipes, to conform with the London County Council regulations for motor garages ?

The tank may be constructed of brickwork and concrete with a series of three divisions, having a concrete roof reinforced with steel joists. The drain from gully would enter the first division at the top. The outgo from each division would consist of a dipping pipe carrying the water from the bottom of one division into the top of the next, the last dipping pipe going to drain. The dipping pipe in the first division would be made shorter than the others, in order to allow more space for the accumulation of grit, which would be washed from the gully inlet into the pit. Each division of the tank would be rendered with cement mortar so as to be watertight. A manhole opening and cover would be provided to each division, so that there would be free access for cleaning

and inspection. In addition, a vent pipe would be carried up from each division and would be connected to the main vent pipe, which would be taken to a safe place in order to carry off the petrol vapour without danger to life and property.

COPPER PIPE FOR GAS WORK

COPPER pipe is being increasingly used for domestic gas installations, and should shortly replace that very unsatisfactory material known as compo pipe.

Advantages

For gas work, copper has the same advantages over iron and lead (including compo) as shown for water (see pages 94-5, Vol. III): cheapness, ease, and quickness of installation, clean and decorative appearance. Any of the forms of jointing used for water pipes can be used equally satisfactorily for gas.

The ease with which copper pipes can be bent, and the absence of cracking often found with brass tubing, are valuable points in favour of copper. With the comparatively low pressure used in gas distribution it is very important that as little as possible friction or obstruction should be offered by the bore of the pipes.

The ordinary iron gas barrel does not show up well in these directions, and many complaints of lack of pressure at stoves or fittings can be traced to defects in the pipes and not to faulty mains pressure.

Screwed Pipe Not Essential

In some cases screwed copper pipe was insisted on for domestic purposes on the grounds of fire danger. Considering that compo pipe with soldered joints was accepted, there was no justification for this regulation, which would largely remove the cost advantage shown by copper over iron and lead, the other advantages, however, remaining.

Gauges Required

For gas work, tubes two or three gauges lighter than the Ministry of Health Model Specification can be used, still further reducing the cost and increasing the ease of handling.

SANITARY SCIENCE APPLIED TO BUILDING

PART IV.—COLLECTION OF RAIN-WATER FROM ROOFS

WE have dealt with various types of roof junctions necessary to render a roof weathertight, and also with various forms of gutters of a built-up character into which rain-water is conducted from roof slopes.

Gutters to Empty Quickly

In order to ensure that the gutters referred to shall be cleared of water as quickly as possible, attention should be directed to the arrangement of the outlet or outlets, so that water shall have an uninterrupted passage to the rain-water pipe.

Cess-pools and Chutes

The lower end of a gutter may be arranged to discharge into a " cess-pool " or drip box, or it can be formed so as to discharge direct into a rain-water head by forming a chute through the wall or at a break in the roof. Cess-pools should be provided with outlet and overflow pipes of adequate capacity (Figs. 1 and 2).

Size of Cess-pool

The sizes of cess-pools vary according to the area of roof surface to be dealt with. There is no hard and fast rule as to size or shape, but they are usually rectangular in shape and of the following dimensions : 18 in. long, 12 in. wide, and 6 in. deep, the outlet pipe for this size being either $3\frac{1}{2}$ in. or 4 in. in diameter. For smaller roofs, 12 in. by 12 in. or 12 in. by 9 in. are suitable. One often finds small sinkings, about 2 in. in depth and 6 in. or 7 in. square, with 2-in. or $2\frac{1}{2}$-in. outlet pipes, provided for use as cess-pools, and on inspection these are invariably found to be partially choked.

Arrangement of Outlet

Wherever possible, the outlet pipe, or " socket " pipe as it is usually termed, should be of the single-bend type, as this gives an easier passage for water and is less liable to become choked. If the single-bend type

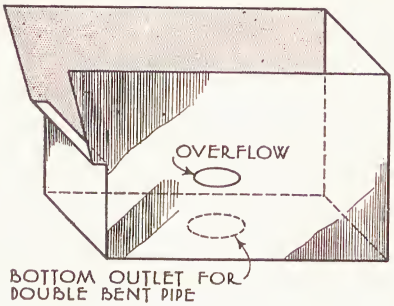


Fig. 1.—18-IN. BY 12-IN. BY 6-IN. ROOF CESS-POOL, SHOWING RELATIVE POSITIONS OF OUTLET AND OVERFLOW PIPE

cannot be adopted then the double-bend pipe must be used, but the bends should be formed to an easy radius. The outlet should be protected by a stout copper-wire guard or, as is often practised, a guard fitted over the whole of the cess-pool (Figs. 3 and 4).

Cleaning Gutters

This is a point which should be mentioned, although not directly concerned with the erection of a new building. The amount of miscellaneous material which finds its way into the gutters on a building is surprising, and it is a good plan to adopt periodical cleaning to prevent entry into outlet pipes of matter which may cause stoppages and consequent damage. This is especially the case where mansard-roof windows open above parapet and cornice gutters. The open window becomes a handy place through which to deposit various oddments, and the gutter forms a convenient receptacle for them. This periodical cleaning is especially necessary where the rain-water is collected and used for various purposes.

Rain-water Separator

Where it is desired to collect the rain-water from roofs it is the usual practice to fix a separator. This is a device which allows the first portion of the rainfall to be utilised for washing the roof surfaces, and then pass to waste. When a given quantity has passed through the separator to the foul-water outlet, the mechanism automatically " cants " and directs the remainder of the water into the clean-water outlet. Such impurities as soot, decaying leaves, bird droppings, etc., are prevented from passing into the clean-water collecting vessel when a separator is used.

Eaves Gutters

These are mainly of two types—half-round and moulded, the latter having flat backs for fixing to fascia boards (Fig. 5). There are variations from these patterns, such as the rectangular and square-section heavy trough gutters. Eaves gutters are usually of plain or galvanised cast iron, galvanised sheet iron, zinc, asbestos-cement, copper, or cast lead. Moulded gutters of wood are also used in some parts.

Shape

To maintain consistency of design in a building, the shape of the gutter should be left to the architect to select.

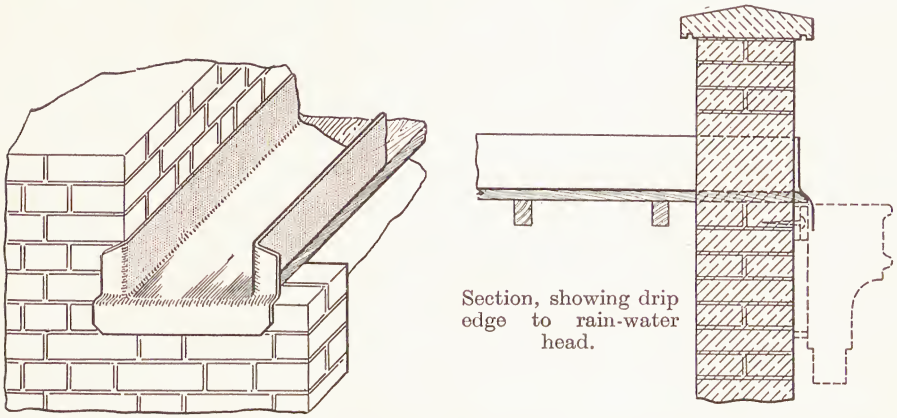


Fig. 2.—GUTTER ARRANGED WITH CHUTE THROUGH WALL AND DISCHARGING INTO RAIN-WATER HEAD

Quality

All good work calls for strong, sound material; the use of shoddy stuff is to be avoided, as it will prove expensive in the long run.

Capacity

In deciding upon the capacity of gutters, consideration must be given not only to the area of roof to be drained, but also to rainfall. Much

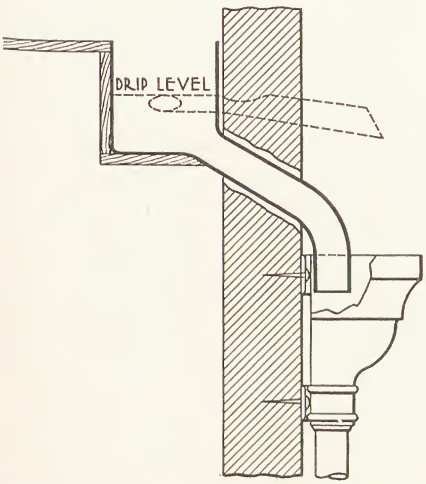


Fig. 3.—CESS-POOL OUTLET CONNECTED WITH SINGLE-BEND PIPE TO RAIN-WATER HEAD

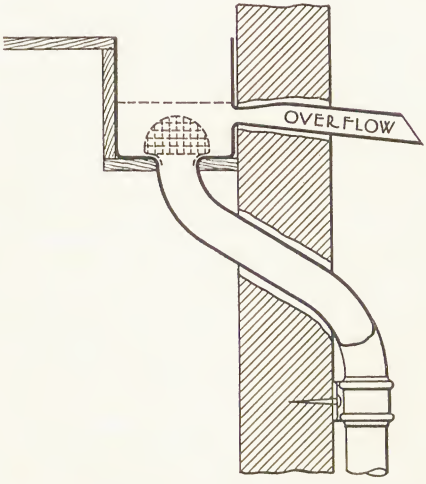


Fig. 4.—CESS-POOL OUTLET CONNECTED TO RAIN-WATER PIPE DIRECT WITH DOUBLE-BEND SOCKET PIPE

The end of the overflow pipe is made elliptical to avoid depth of opening.

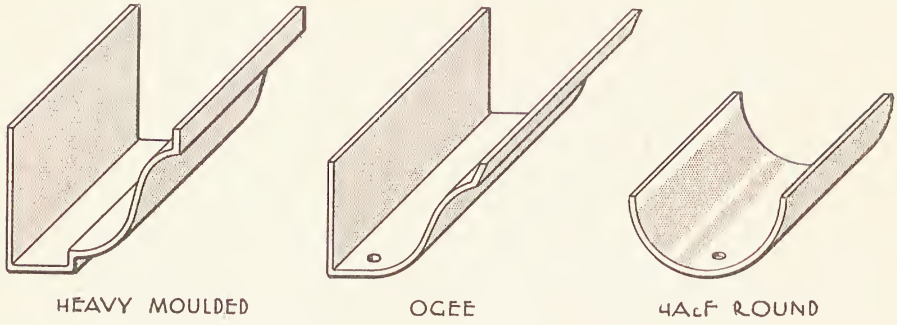


Fig. 5.—TYPES OF EAVES GUTTERS

inconvenience and damage may be caused by a system of gutters which has been planned to cope with a normal rain, and which has proved totally inadequate to deal with the volume of water falling upon a roof during storms. Where a building is in the neighbourhood of trees, there is always the possibility of stoppages due to falling leaves, and this should be taken into consideration.

Outlets

These are usually in the form of what are termed "nozzles," and in many types the outlet pipe is absurdly small. This is an important point to consider, and the minimum diameter of the outlet for ordinary house gutters should be not less than $2\frac{1}{2}$ in. in the clear. The frequent stoppages which occur in small gutters having outlets of $1\frac{1}{2}$-in. or $1\frac{1}{4}$-in. diameter is sufficient evidence to prove this statement. It is also fairly common practice to fix a $2\frac{1}{2}$-in. or 3-in. pipe to conduct the water away from gutters having these undersized outlets, when a smaller size would answer the purpose equally well.

Fall

There is no hard and fast rule governing the amount of fall required. The construction of the roof will in most cases be the deciding factor, but 1 in. in 10 ft. is sufficient fall to permit of a gutter clearing itself providing there is no impediment in its course. It should, however, be pointed out that much guttering is fixed with less fall than that given above, and this often happens on a very long run to one outlet. A better plan would be to divide the fall in two directions and provide an extra outlet and rain-water pipe.

Fixing

The best method of fixing eaves gutters is undoubtedly by the use of proper brackets, made to fit the gutter and to suit the wood- or steel-work of the roof on which they are used (Fig. 6). The ogee and other moulded

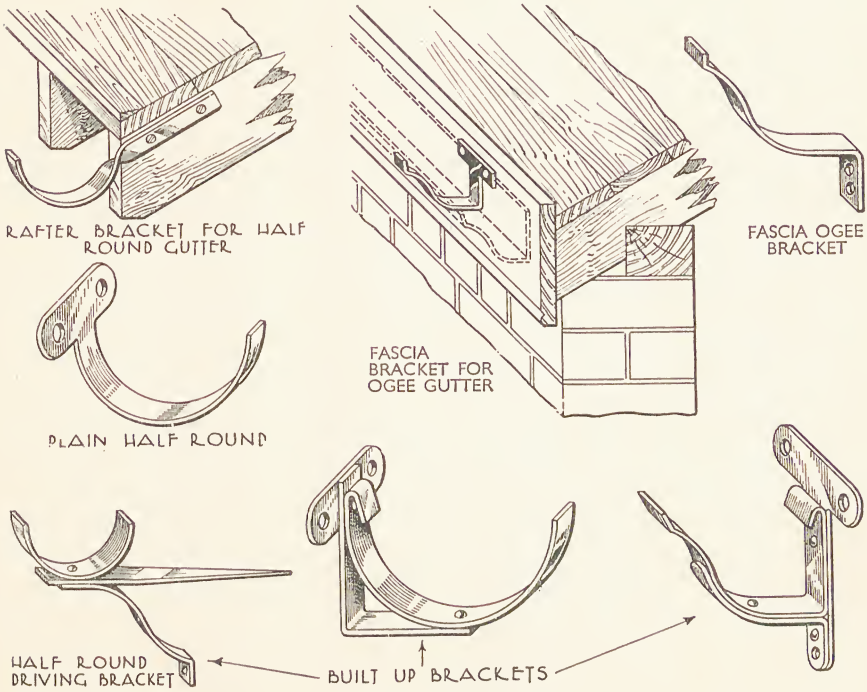


Fig. 6.—TYPES OF GUTTER BRACKETS

gutters are provided with screw-holes for fixing to fascia boards, but this method is not to be recommended. The screws hold the gutter too rigidly, and do not allow for any movement due to expansion and contraction ; this often causes the joints to leak, due to the drying out of the jointing medium, which cracks under the strain. Cast iron expands less than most common metals, but even so, assuming that a 30-ft. run of gutter is exposed to a range of temperature of 90°, the total expansion will be approximately $\frac{3}{16}$ in., and as such expansion is an irresistible force, this amount is sufficient to cause fractures and must be taken into account.

Weight of Gutter

The weight of the gutter, together with that of the dirt which accumulates and the water carried during rainfall, is another factor which calls for the use of bracket supports, in addition to the reasons set out above.

Joints are of the spigot and socket type, and should be made with a suitable oil cement or elastic cement which will prevent drying out occurring too rapidly. Putty composed of white lead and red lead, or painter's putty and red lead, is often used for jointing. Ordinary

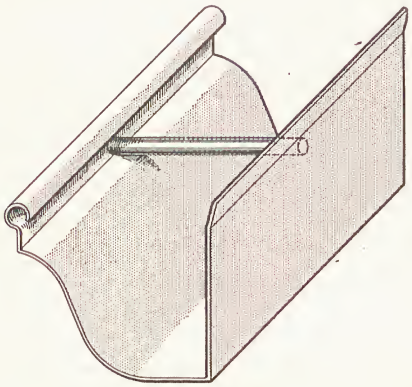


Fig. 7.—ZINC GUTTER FROM BACK, SHOWING TUBULAR SUPPORT

painter's putty, whether mixed with red lead or used alone, is not a good medium, as it dries out very quickly. The use of white lead alone is considered by many to be a good jointing material, as it retains its elastic properties much longer than when mixed with red lead. The gutter bolts, washers, and screws for jointing and fixing gutters should be galvanised as a protection against rust.

Zinc Guttering

Owing to the nature of the material, the usual method of fixing this type of gutter is by means of long, galvanised-iron screws being passed through the tubular supports which are soldered inside the gutter at fairly close intervals. The joints are formed by slipping the end of one length of gutter within the next length sufficiently to give a reasonable lap, and soft-soldering the joint with a copper bit (Fig. 7).

Protection

Cast-iron gutters need protecting against the ravages of rust, and unless they are galvanised, the backs of the gutters—where fixed flat against a fascia board—cannot be coated or painted once they are fixed without, of course, removing them. Plain, cast-iron guttering should be painted at least twice, inside and outside, before fixing, and this should be carried out with a suitable type of paint such as " Anodite " anti-rust paint, and it should be observed that the *inside* as well as the *outside* of gutters needs painting at intervals after they are fixed, if they are to serve their purpose well. The fixing of cast-iron gutters without first painting or protecting them is bad practice, and should be condemned.

" Everite " Asbestos-cement Gutters

Gutters of this material are becoming increasingly popular for both domestic and industrial buildings, as it is being realised that considerable saving can be effected in initial cost and maintenance charges. They are light, easily fixed, and harden and increase in strength after fixing. Unlike cast iron they do not corrode, and require no painting or other preservative treatment either at the time of fixing or subsequently. They are made in a variety of patterns suitable for almost any purpose. Right- and left-hand socketed lengths are obtainable, as well as the usual fittings applicable to cast iron, such as angles, nozzles, stop-ends, etc.

Fixing and Jointing

This class of gutter should not be fixed direct to a fascia board, but should be supported on specially shaped brackets which are obtainable for the purpose.

For the joints a special composition is recommended, and which remains ductile for a considerable length of time, thus allowing for slight movement of the gutter without fracturing the joints.

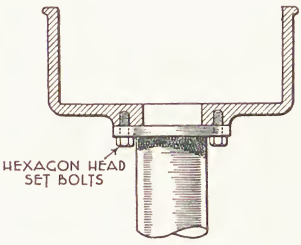


Fig. 7A.—FLANGED OUTLET PIPE FITTED TO HEAVY CAST-IRON TROUGH GUTTER

Cleaning Eaves Gutters

The same remarks apply to eaves gutters as to those of the built-up type, and periodical cleaning-out should be adopted.

Rain-water Data

1 in. of rainfall = ·52 gal. per square foot.

1 in. of rainfall per 100 sq. ft. of collecting surface = 52 gal.

1 in. of rainfall per acre of collecting surface = 101 tons or 22,625 gal. of water, approximately.

Area of collecting surface in square feet × available rainfall × ·52 = gallons.

Area of collecting surface in square feet × half-rainfall in inches = gallons (4 per cent. error).

Example 1.—3,500 sq. ft. of roof. Available rainfall, 3 in., ∴ 3,500 × 3 × ·52 = 5,460 gal.

Example 2.—3,500 × 1·5 = 5,250 gal.

Rain-water Pipes

In order to conduct the water away rapidly from the gutters, it is a good policy to provide rain-water pipes of ample capacity and in sufficient numbers. One must, however, bear in mind what effects such pipes will have on the appearance of a building, and arrange their positions accordingly. It is obvious that ordinary, plain pipes do not enhance the beauty of a building, especially when a number of them is required, and it is also desired to maintain consistency of design.

One has the choice of a variety of pipes made of cast iron, and it is generally possible to decide on a type that will fulfil the requirements; failing this, special castings may be made for the purpose.

Cast Lead

This is an excellent material to use for the purpose, and it may be fabricated to suit any particular style of architecture.

The whole of the equipment, including bends, offsets, etc., may be made up from sheet, and all seams burnt together by the autogenous process.

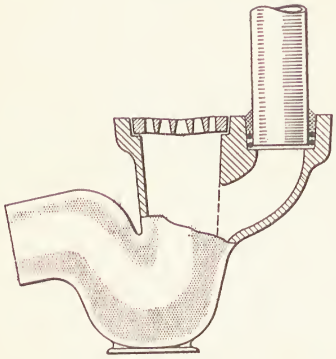


Fig. 8.—RAIN-WATER PIPE CONNECTED TO RAIN-WATER DISCONNECTING TRAP

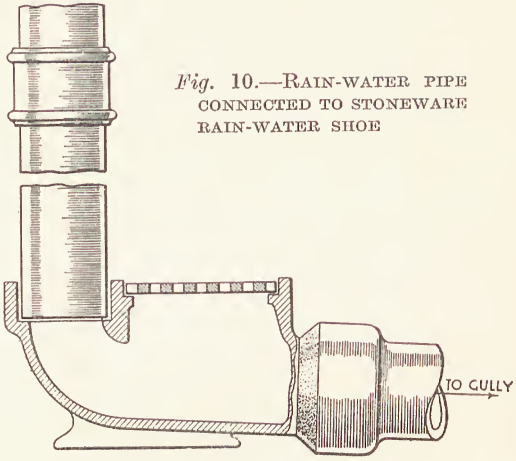


Fig. 10.—RAIN-WATER PIPE CONNECTED TO STONEWARE RAIN-WATER SHOE

Expansion and Contraction

The question of damage to lead pipes due to expansion and contraction of the metal does not arise with rain-water pipes of this material, as the spigot and socket type of joint allows the pipes freedom to move. Leaden rain-water pipes will last almost indefinitely, and should repairs or re-instatement be necessary the lead may be melted down and re-cast. If this is not desirable, the old lead is of value, whereas old cast iron is worth but a very small amount.

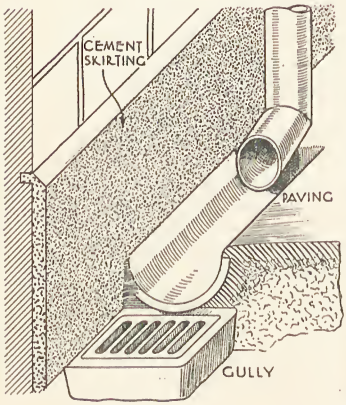


Fig. 9.—RAIN-WATER PIPE DISCHARGING INTO SHORT CHANNEL LEADING TO WASTE-WATER GULLY

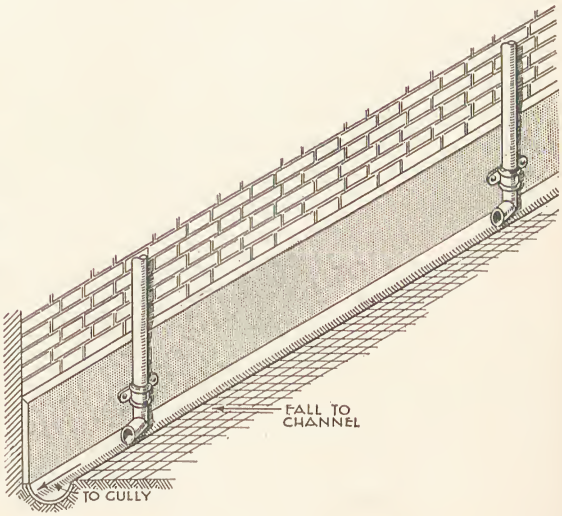


Fig. 11.—DISCHARGE OF RAIN-WATER PIPES INTO CHANNEL FIXED ALONG BASE OF WALL

Discharge of Rain-water Pipe at Foot

The manner in which the lower end of the rain-water pipe is dealt with varies in different districts, and is also dependent upon the type of drainage system in use. In many parts, provision is made to direct the rain-water to a storage reservoir, from where it may be pumped and used for various purposes, whilst in others it is made to discharge into a soakaway or into a soil or surface-water sewer. The collection, storage, and filtration of rain-water will be dealt with in another section. The method of treatment of the lower end of the rain-water pipe is usually one of the following: (1) Connected direct to rain-water disconnecting trap (Fig. 8). (2) Discharging into a channel leading to a gully receiving waste matter (Fig. 9). (3) Connected to a rain-water shoe and drain leading to a master gully (Fig. 10). (4) Discharge into channel along base of building, and conducted to a gully at end of channel (Fig. 11). (5) Discharge into roadway gutter (Fig. 12). (6) Discharge into drain connected to soakaway (Fig. 13).

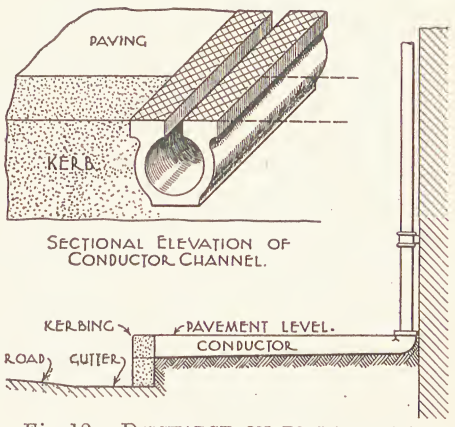


Fig. 12.—DISCHARGE ON TO ROADWAY

Joints

The question of caulking joints of rain-water pipes is mainly one of opinion. The ordinary socket and spigot does not leave much annular space for packing, and whilst it is often considered necessary to pack the joints with a suitable medium, such as strands of hemp and red-lead putty, in many cases it is deemed unnecessary. The reason for this is, should one of the lower lengths of a stack of pipe become blocked up, the lower joints will leak and give warning of the stoppage. If, however, the joints are made watertight, it is possible for the pipe to become filled to the top before any leakage occurs from the joints. This has been known to happen with a rain-water pipe fixed inside a building, resulting in much damage from the fourth floor down to the ground floor before the stoppage became known. Where

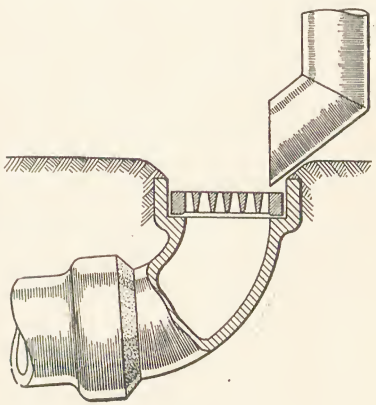


Fig. 13.—RAIN-WATER PIPE DISCHARGING INTO BEND FOR CONVEYANCE TO SOAKAWAY

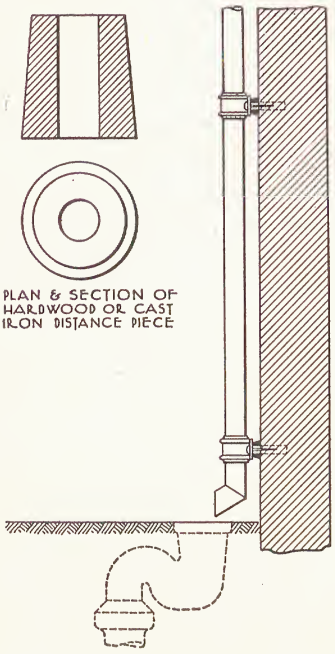


Fig. 14.—METHOD OF FIXING PIPES CLEAR OF WALL BY USING HARDWOOD OR CAST-IRON DISTANCE PIECES

a rain-water pipe is used as a drain-ventilating pipe, then, of course, the joints should be effectually packed. This is sometimes permitted in certain parts of the country, but in such cases, large-socket pipes should be used which will permit of proper jointing.

Fixing

The type of fixing depends upon whether the pipes are provided with ears. The method which has been used for years, and which is still practised by many, is to have pipes with ears cast upon the socket and which lie flat against the wall ; pipe nails are passed through holes in the ears and driven into plugs fixed in the wall. Experience has proved that this method is not good, and it is better to keep the pipes clear of the wall by inserting hardwood or metal "bobbins" or distance-pieces between the wall and the ears or "lugs" of the pipes (Fig. 14). Much better still is to use pipes having special ears which lie flat against the wall, but keep the pipe well clear for inspection and painting.

Pipes without ears are fixed by the use of holderbats (shown in Fig. 15), which should be galvanised.

Protection

Like cast-iron gutters, rain-water pipe should be protected against rust by galvanising, painting, or coating with suitable solution.

It is sometimes specified that the interiors of pipes are to be treated with a suitable solution before fixing. Hot tar and pitch or black varnish are often used for the purpose, and are applied by a brush similar to a flue brush, which is passed through the pipes. Dr. Angus Smith's solution may also be used as a protective coating, but pipes which are to be subsequently painted must be specially treated before the paint is applied.

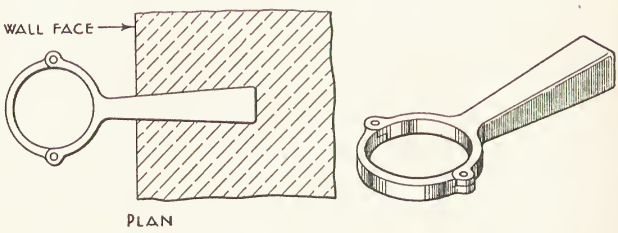


Fig. 15.—HOLDERBAT FOR FIXING PIPES

BENDING COPPER TUBING

THE methods employed for bending copper tube may be classified under three heads, namely :—

(1) Loading.
(2) Bending machines.
(3) Springs.

Small-diameter pipes up to ½ in. may easily be bent unloaded by hand manipulation after the section requiring bending has been annealed.

The Loading Method

The " loading " of tube for bending has been carried out for many years, and was the only method by which successful bending could be performed. Loading consists of filling the tube with a suitable material which will prevent flattening or kinking occurring during the bending process. The filling may be sand, pitch, resin, or lead.

Loading with Sand

Sand is an excellent filling medium provided it is well tamped into the tube. The sand must be perfectly dry and of fine grain. A plug is securely fixed in one end of tube and sand is passed into the other end until the tube is full.

In order to pack the sand as tightly as possible, the sides of the tube should be tapped gently with a piece of soft wood whilst the sand is being passed in, and when the tube is full the other, open, end should be securely plugged.

Using a Sand Compressor

There is an excellent apparatus now obtainable for bending by sand loading which dispenses with the need for filling the whole of the tube with sand. This is the " Enpee " sand compressor ; with this tool it is necessary only to fill so much of the tube as required for the actual bend. The sand is kept tightly compressed by operating a screw-spindle whilst bending is in progress.

Loading with Pitch and Resin

When either of these materials is to be used for loading purposes, it is necessary first to thoroughly anneal the tubes, for unlike sand-loaded tubes, they are bent cold.

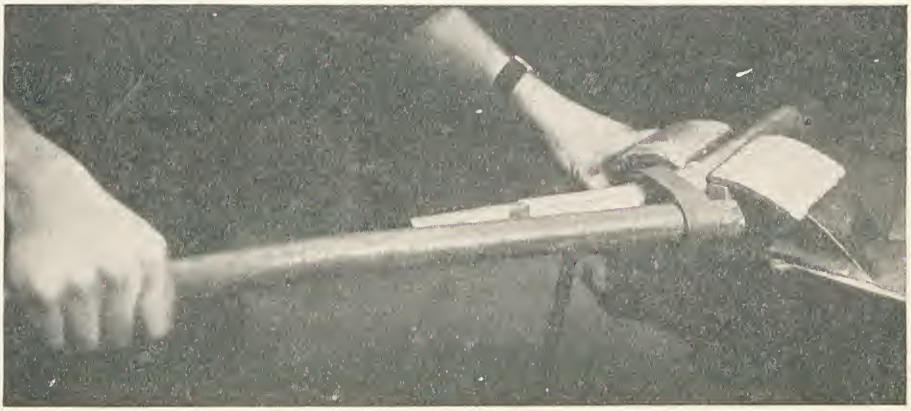


Fig. 1.—HAND-BENDING WITH COLLAR AND VICE

This shows a method of bending 1-in. annealed tube loaded with pitch, resin, or lead. As shown, the tube is bent cold. It is gripped in vice between two asbestos clamps, and the bend is made by levering on iron pipe attached to tube with iron collar. Note piece of wood between iron and copper pipes.

After annealing, the tubes should be heated slightly to allow the filling medium to run in freely and form a solid mass.

A plug of wood is driven into one end of the tube, which is then stood upright with the open end at the top. Use a funnel through which to pour the liquid filler, as the filling can then be carried out without a pause by pouring from a lipped container in which the filler is melted. The shrinkage which takes place on cooling must be compensated for by the addition of more filler in order to fill the tube. To do this it will be necessary first to melt, with a blowpipe or lamp, the top of the previous filling. Great care must be exercised in the heating and filling process, owing to the inflammable nature of these materials. The tubes must be kept in an upright position until the filling has solidified completely, and bending must not be commenced until this has taken place.

Lead Loading

In this case it is advisable to anneal the tube beforehand. As with resin and pitch, the end of the tube must be plugged, and after the tube has been stood on end it should be made fairly hot throughout its length before pouring in the molten lead. Pouring in should be as continuous as practicable. Keep the pipe hot with a blowlamp whilst filling is being done, in order to ensure there is an unbroken fill throughout the tube.

As soon as the lead has solidified bending may be commenced, and the work is made much easier if this is carried out whilst the lead is hot.

Unloading

When bending is finished the loading material must be removed completely from the tube.

Sand is the easiest filler to remove, and requires no heat ; after removing the plugs, the tube should be tapped gently with a piece of soft wood in order to remove any grains of sand that might cling to the inside of tube. This will usually be found sufficient to dislodge them, but it is sometimes expedient to wash the interior by the insertion of a hose pipe.

Lead, pitch, and resin all require heat to remove them, and in removing these fillers the heating must always be applied at the extreme end of the pipe so that the emptying is gradual and at the same time complete. It is also dangerous to apply heat at any other point along the tube, as the expansion may cause a plug to blow out, with possible injury to workmen. Another danger is the liability of a sudden emission of semi-molten filler from the tube, due to uneven heating during the unloading process.

BENDING SAND-LOADED TUBES

Obviously, the first thing to do is to make a wire template of the bend or bends, or to set out the job on a suitable surface, such as a sheet of iron or cement-faced floor.

The position of the bend should be marked on the tube in chalk, and heat applied until the tube is red hot ; the length of the " heat " will be governed by the type of bend to be made, and it may be necessary to reheat the pipe several times ; it is not advisable to attempt to bend too much at a time. The heating must be evenly distributed, or an uneven radius will result.

The bending may be carried out on a bending block or former, or one end of the tube may be held in suitable clamps in a bench vice and the other end pulled round as required to form the bend. Various devices may be made up in the shop or on the job to accomplish many bending operations of this description.

Removing Ripples and Bulges

As the actual bending is in progress the throat or inside of the bend may show signs of puckers or ripples, especially if the loading has not been thoroughly carried out. It is not always possible to avoid ripples, but should they appear, they must be worked out immediately before proceeding with the bend. This may be done successfully from the outside if they are not too deep.

Ripples are usually accompanied by slight bulging of the sides of the tube and this bulging should be worked back first, after which the throat of the bend may be worked back to position, the tools used for this purpose being largely a matter of choice on the part of the operator. Smooth-faced hammers with flat and rounded panes may be used, whilst mallets and rounded dressers of very hard wood are sometimes preferred.

The formation of ripples will, of course, depend upon the type of bend

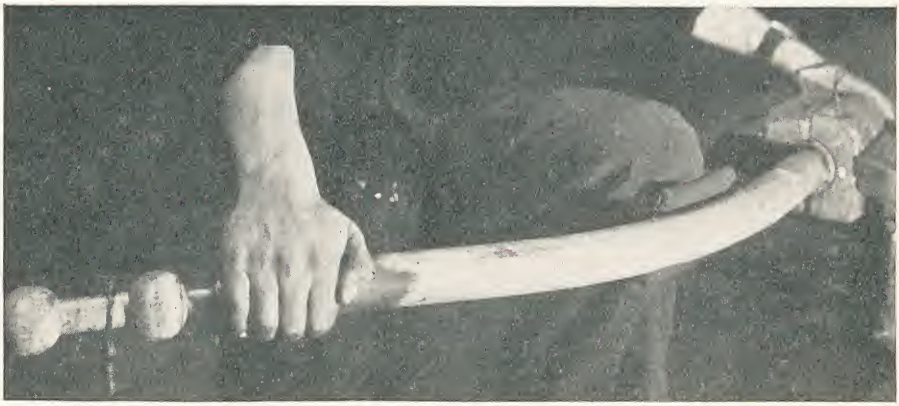


Fig. 2.—HAND-BENDING WITH SPRING

Pulling bend in annealed 1½-in. diameter tube over knee. Note spring inserted in tube, and special clamps to prevent damage to pipe whilst held in vice.

being made, and the sharper the radius the more likelihood of ripples occurring.

With easy bends the tube may flatten slightly, with bulging of the sides, and a slight opening of the bend will usually remedy this condition.

Removing Ripples on Large Tubes

With the larger-sized tubes, any slight rippling may be removed after unloading by using a heavy-pattern bent bolt and hammer, and if the bend is in a position to make this impracticable, an iron bobbin may be passed through on a steel cable and the ripples hammered out carefully on the bobbin. Here again care must be taken to see that the back of the bend is not damaged by the bobbin during its passage through the tube, also that the correct hammers are used, so that ugly marks do not appear. It is essential that the faces of the hammers be kept perfectly smooth and bright.

Bending Lead-, Pitch-, and Resin-loaded Tubes

The bending of these tubes is practically the same process in each case, the chief differences being that lead-loaded tubes may be bent whilst hot, and bends may be made nearer to the end of the tube than with resin ; on the other hand, resin- and pitch-filled tubes require less power to bend than do lead-loaded tubes. They are, of course, much lighter to handle, and this is important when fairly long lengths are to be bent.

Useful Tools for Bending

A simple form of bending apparatus may be made by using a circular piece of wood and an eye-bolt. These can be fixed to the bench, and using

the eye-bolt to hold the end of the tube the block is used as a former on which to pull the pipe to the required sweep. A number of these blocks can be made to different diameters to suit almost any type of bend, and eye-bolts of different sizes to suit various tubes. A few holes in the bench will allow of different positions for the blocks and bolts. The blocks may, if desired, be sheathed on the circumference with thin sheet-iron; this is useful to prevent scorching should it be desired to bend heated tubes.

Another method for bending is by using a vice and special shaped clamps in which to grip the tube, which in turn is bent to the required shape with the aid of a lever and iron bending collar.

A Bending Block

An improvised form of bending block similar to that used by electricians for bending conduit may be made very simply. A piece of 2½-in. by 4½-in. or 3-in. by 6-in. deal about 3 ft. long is required ; two or three holes should be bored through, a little larger than the tube to be bent ; the ends of the holes should be gouged to a radius to prevent damage to the tube during bending. This is suitable only for bends of easy radius, but is quite a useful method and easily prepared when on the job if other means are not available.

Bending with Springs

Copper tube of diameters up to 1½ in. may be bent with steel bending springs, providing that sharp bends are not required.

These springs are made of square-section spring-steel wire, and are inserted into the tube by a twisting movement until the position of the bend is reached. It is essential first to anneal the tube.

The bending may be carried out on a wood former or block, or as in Fig. 2.

When completed, the spring is removed by twisting and pulling forward at the same time.

Polished tubes, provided they have been annealed, may be bent by this process, as no hammering or dressing to remove marks is required.

Bending with Machines

The bending of copper tube is carried out easily and efficiently in a machine of which there are now quite a number of excellent types from which to choose. The question of economy should be studied when dealing with practical efficiency, and the saving in cost of fittings, when a bending machine is available, is a considerable item even on a small installation. The " Hilmor " bending machine is described on pages 49 to 52, Vol. III.

These machines are made in various sizes to suit different ranges of tubes, and many of them are fitted with interchangeable formers and guides for bending copper, iron, and steel tubing from ½ in. to 4 in. in diameter. The smaller types are operated by hand levers with a direct pull, in some cases up to 2-in. diameter, the larger machines being fitted with gearing. Light, portable tube benders are also available, and these may be easily moved about from one part of a job to another, so that bends may be made as required.

Loading is unnecessary in the case of the smaller sizes of copper tube, but above 2-in. diameter it is deemed advisable to load the tube, especially if bends of a difficult type have to be made.

Heating Pipes for Bending

There are several methods of heating pipes for bending, including the portable forge, ordinary plumber's blowlamp, and air furnace.

For larger pipes, the necessary heat is best applied with a blowpipe, using coal gas and compressed air, or with an oxy-acetylene blowpipe with a large tip to give a good-sized flame, so that the heating process is not prolonged. By using this form of heating, the pipe may be kept in the vice during the whole operation. For the smaller tubes, a powerful oil blowlamp may be used.

A special multi-jet blowpipe tip arrangement has been designed for use with the oxy-acetylene blowpipe and produces a high local heat over a fairly large area of metal. In this respect the blowpipe fitted with the multi-jet tip performs the same functions on a smaller scale as the portable forge. The multi-jet provides a flame approximately 3½ in. wide, and heat can therefore be raised quickly over a considerable area by suitable movement of the blowpipe. The jet may be used either on the high-pressure system or on the low-pressure system using a generator.

The oxy-acetylene blowpipe will be found useful where it is necessary to alter or adjust bends after being fixed.

SANITARY FITTINGS

MODERN sanitary appliances and fittings, such as water-closets, sinks, baths, lavatory basins, slop sinks, and bidets, may be obtained in a great variety of shapes and in various colours, to conform with practically any requirement or scheme, from the simple sanitary fitting manufactured solely for strength and hard wear combined with economy, to what one might term luxury fittings designed to fit in with the standard and colour scheme of the first-class job.

Selection and Construction

Nowadays the primary consideration in the selection of sanitary fittings is probably the question of type and cost. The manufacture of sanitary fittings has in recent years been so much improved, due to the demands of sanitary science, that it is practically impossible to purchase a sanitary fitting that does not conform constructionally with modern requirements.

It is necessary, however, that the following details should be borne in mind in the selection of sanitary fittings :—

(1) Simplicity of form, and designed to permit easy cleansing. Freedom from complicated and unnecessary parts.

(2) Constructed of a hard, durable material, with a smooth, well-glazed surface.

(3) The outlet so formed that a good and reliable connection can be made with the pipe into which the fitting is to discharge.

Sanitary Pottery

All sanitary pottery is made from some form of clay and glazed over. There are three main and distinctive classes of pottery used in the manufacture of sanitary appliances, and the names given to these recognised forms of pottery are " earthenware," " fire-clay," and " cane and white " ware.

Earthenware

Earthenware is a pure white pottery with a very fine texture, and contains a mixture of various clays with stone and flint. The clay and china stone are found in Cornwall and Devon, and the flint is a variety of the seaside pebble ground into powder.

Fire-clay

Fire-clay is a buff-coloured clay of tenacious character, and it is this tenacity which enables it to be successfully used in the manufacture of sanitary pottery.

Cane and White Ware

Cane and white ware is really an inferior kind of fire-clay. Its uses are limited because it is not possible to make large pieces of pottery from it. It is the poorest of the materials used in sanitary pottery.

Manufacture

Sanitary pottery is now chiefly made by the process of casting. The clay is kneaded into a creamy liquid with the addition of water, and is then poured into a cast made of plaster of Paris. Plaster of Paris is used because this material readily absorbs the moisture from the liquefied clay. Most casts or moulds are made in two pieces, so that the clay is run into the intervening space. The plaster of Paris draws off the water, and after a time the mould is separated, leaving the article plastic and dry enough to be handled.

Water-closets are sometimes cast in a single mould representing the outside of the pan, which is filled right up to the top with liquid clay. The plaster of Paris absorbs the moisture evenly, and after about 2 hours the clay that is still liquid is run off, leaving a thickness of plastic clay on the mould sides. The potter has then to work on it to produce an even surface.

After casting, the pieces are placed in a hot room to dry for about a week. They are then placed into an oven and fired for $2\frac{1}{2}$ days at a temperature of 1,200° C., and then gradually cooled down.

Glazing

Glazing consists of dipping each article into a vat of glaze liquid, and the skill of the dipper is depended upon largely for an even surface of glaze on the finished article.

The pieces are then taken to a second oven and fired for 36 hours. This causes the glaze to fuse evenly. Sixty hours is then allowed for cooling.

Fire-clay is produced on similar lines, but as it is a heavier ware, dipping in glaze is not resorted to ; moreover, as the body itself is not white, an enamel substance is painted on with a brush after the casting is thoroughly dry. About six coats of enamel are applied, and then the glaze.

An essential difference between the production of fire-clay and earthenware is that fire-clay is fired only once, while earthenware is fired twice.

Coloured Ware

The method of making coloured ware is just the same with the exception that the colour is introduced into the glaze. The firing process is, however, more difficult, as care has to be taken to keep it at a temperature that will safeguard against crazing and at the same time avoid destroying the colours.

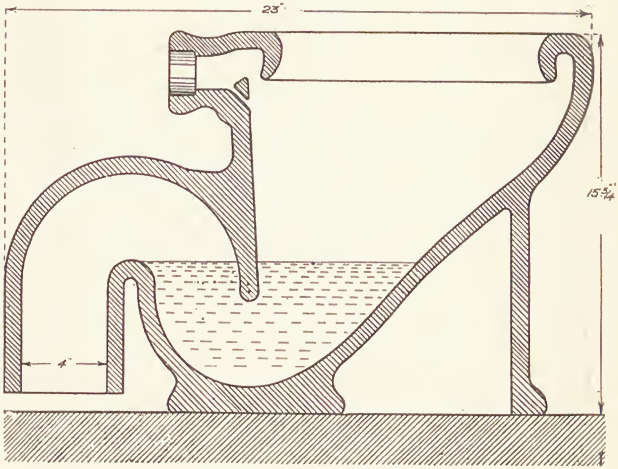


Fig. 1.—PEDESTAL-TYPE WATER-CLOSET WITH FRONT SKIRTING

CLOSETS

Types

Closets for the deposit of excreta, etc., may be considered primarily to be divided into two distinct types : those which are connected to a drainage system and flushed with a quantity of water ; and the earth-closet, which may be used with advantage in country districts and villages where the limited character and means of water-supply will not permit the water-closet system to be adopted.

Principle Involved in the Earth-closet

The principle involved is one of discharging a quantity of dry loam or earth over the deposited excreta, thereby setting up nitrification due to the action of the bacteria contained in the earth upon the organic matter, which tends to hasten its conversion into inorganic compounds. Sand, ashes, and other similar substances are not suitable for use. The contents of the closet are subsequently dug into the land, where more recent deposits of excreta are broken down, the whole being useful from a manuring point of view.

Appliances Required

The earth-closet consists of a galvanised iron pail, with cabinet seat on bearers, and a metal earth container so situated at the rear in order that a quantity of earth may be discharged from the container into the pail by means of a metal baffle-valve. The valve may be supplied with a handle for hand use, or it may be connected with a self-raising seat by a system of levers, so that when the seat rises the valve opens and shuts, allowing the correct quantity of earth to be discharged.

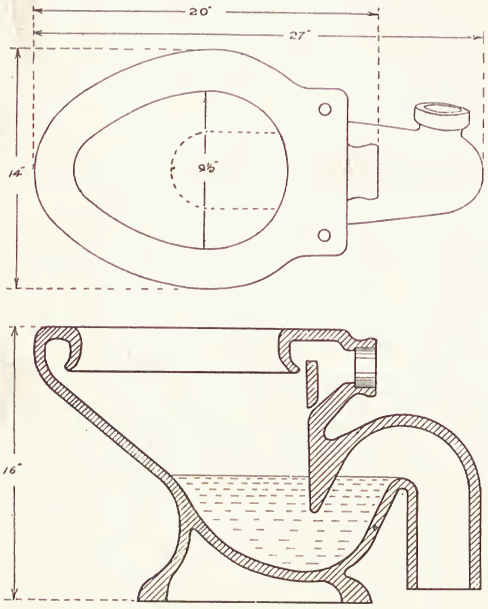


Fig. 2.—PEDESTAL-TYPE WATER-CLOSET WITH SEMI-BOX FLUSHING RIM

An underseat is provided, to which is connected a galvanised or enamelled iron rim for the purpose of directing urine and matters into the pail. The capacity of the pail may be either 3 or 4 gal., and the earth container to hold from $1\frac{1}{2}$ to 2 cu. ft.

Situation

The closet should be housed in a specially built, well-ventilated apartment, well away from the house or building, in order to obtain aerial disconnection. The walls and floor should be constructed of an impervious material, and preferably rendered in cement and sand, trowelled to a smooth surface, or with some other equally suitable material.

Water-closets

Modern water-closets may be divided into four types : (*a*) the pedestal wash-down closet, (*b*) the corbel closet, (*c*) the siphonic closet, and (*d*) the valve closet.

All four types can be obtained in a variety of patterns and shapes to suit the purpose and class of work for which they are required, or for a particular job that one type or the other may better suit.

A water-closet pan is fitted with either a P- or S-trap, and in ordering or specifying it is necessary that the type of trap should be stated. With the majority of water-closets used nowadays, excepting perhaps the valve closet, the trap is an integral part of the fitting. Two-piece closets, with the pan separate from the trap, may be obtained. In some cases the trap may be of lead, and in such cases the inside of the trap is usually glazed. The advantage of a two-piece closet is that the outgo may be turned at a different angle from that of a combined pan and trap, and thereby suit the position of a soil pipe that cannot be arranged for a one-piece closet. Further, a lead trap is better and more easily connected to a lead soil pipe, and is to be preferred where there is very much vibration that would be likely to crack a trap made of stoneware.

Pedestal closets with P-trap may be obtained with the outgo facing the rear, or turned left or right.

Pedestal Wash-down Closets

A good form of wash-down water-closet should have an almost vertical back, in order that matters may fall free into the water contained in the trap.

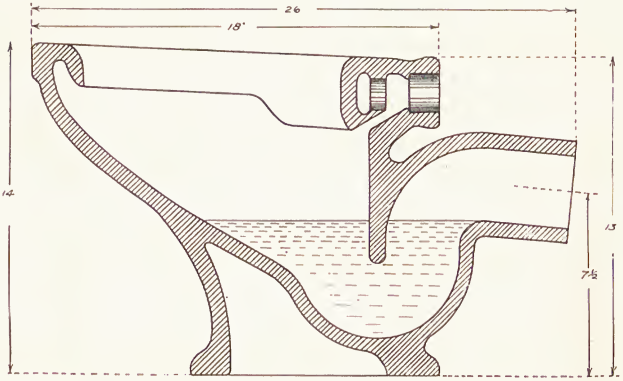


Fig. 3.—WATER-CLOSET DESIGNED WITH THE BASIN SLOPING BACKWARDS

The amount of water area should be compatible with the amount of water allowed for flushing purposes, as with this type of water-closet the water contained in the trap, together with its contents, is dependent on removal and refill by the flushing water alone.

Fixing

The pan should be well bedded and screwed down to the floor before the joint to the soil pipe or drain is made, and at the same time care taken to see that the pan is fixed level.

Pans fixed to wooden floors should be bedded down with red and white lead, and to cement or concrete with cement and sand. Wooden blocks may be fixed in the concrete to receive the holding-down screws.

By bedding down and securely fixing, it is ensured that no after-movement of the pan will take place due to its use, and that no strain will be made on the outlet.

Making the Joint to the Outgo

A P-trapped pan on an upper floor may be joined to a lead or iron soil pipe by means either of yarn and red and white lead, or with yarn and neat cement. An objection to the use of neat cement for this joint, when the pan is fixed to a wooden floor, is that if shrinkage takes place in the timber a great strain is placed on the rigidly fixed outgo, and fracture is likely.

For a red and white lead joint the socket and the spigot of the pan should first be painted. Alternate rings of red and white lead and yarn are then caulked into the joint, a ring of yarn being placed in first to prevent the likelihood of the red lead entering the pipe.

With cement joints, whether between pan and soil pipe or pan and drain pipe, a ring of yarn should be placed in the socket first to prevent the entry of cement to the inside of the pipe, and then the annular space filled up with neat cement, finishing with a trowelled surface to an angle of 45°.

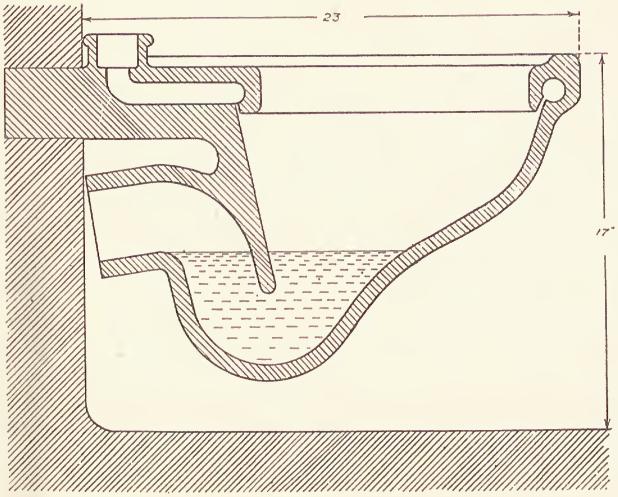


Fig. 4.—WHITE-ENAMELLED FIRE-CLAY CLOSET WITH INTEGRAL CORBELS FOR BUILDING INTO WALL

Making the Joint between the Flush Pipe and the Pan

The joint between the flush pipe and the pan may consist of one of the many patent connections for this purpose which are on the market, a rubber cone may be used, or a lead washer known as a "star washer" may be cut and fixed by the plumber. The purpose of the "star washer" is to retain a quantity of jointing material, such as red and white lead, in the flush-pipe socket, and if properly made and fixed is a sound and lasting job.

Great care must be taken in fixing the flush pipe that the end of the pipe does not protrude into the pan farther than the depth of the flush-pipe socket. Failure to observe this may result in a poor flush. To guard against this, and to ensure that jointing material if used does not obtain access to the pan, the end of the flush pipe should be opened out with a tan pin so that it fits in the socket.

Pans with an upturned inlet nozzle to the flushing rim facilitate a better connection with the flush pipe than those having horizontal nozzles.

Corbel Closets

Corbel closets derive their name from the fact of the corbel principle being used for their support. This corbelling out takes the form of either an extension piece, cast integral with the closet and built into the wall, or by cantilever brackets also built in.

The chief advantage of the corbel closet is that it is fixed free of the floor. This allows the whole closet surround to be washed out or cleansed, thereby setting up a hygienic condition.

The corbel closet is considered to be very suitable for hospital or institutional use, but is by no means confined to this class of work.

When fixed in conjunction with cantilever brackets built into the wall, holes or slots are provided in the pottery for the brackets to enter. The advantages of this type are that the pan is entirely clear of the wall, allow-

ing facilities for a hose to be passed down the back of it, and also, should the pan be broken, it can be smashed off the brackets and replaced without cutting away the wall.

The seat is usually hung on pillar brackets or hinges so that it rises clear of the basin, and there is no inaccessible space for lodgment of dirt and germs.

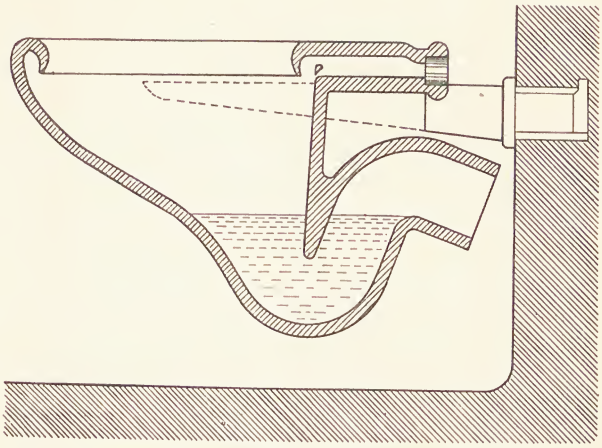


Fig. 5.—CORBEL-TYPE WATER-CLOSET FITTED ON BRACKETS BUILT INTO WALL

The Valve Closet

At the present day the valve closet is not so much used as formerly, possibly because the cheaper forms cannot be considered satisfactory, and also on account of the demands of modern by-laws in respect of water supply and sanitation.

Consequently, unless the expense of a really high-class arrangement can be considered, it is better to use a more simple type of water-closet.

The principal features of a good type of valve closet are :—

(1) The basin to hold a fairly large quantity of water, which should have a surface area larger than the opening in the seat. This permits deposits to pass into the water and be submerged without fouling the sides of the basin ; also, that gases emanating from them are condensed and rendered less offensive. The large water content provides for adequate dilution of the liquid portion of the deposit.

(2) A properly trapped overflow should be provided to the basin, and be so constructed that it is effectually flushed with clean water each time the apparatus is used. This overflow to discharge into the valve box.

(3) The conductor arm or valve box should be ventilated to the external air.

Action

The retaining valve is opened by a lift-up-action lever, so that the water and added matter in the basin are conducted away in the form of a water envelope, through the trap, into the soil pipe, and thence to the drain. The flushing water immediately cleanses the sides of the basin, the retaining valve closes, and the basin is recharged with clean water. The flushing water is admitted through a valve which is opened by a lever connected to the retaining-valve lever. The closing of the supply

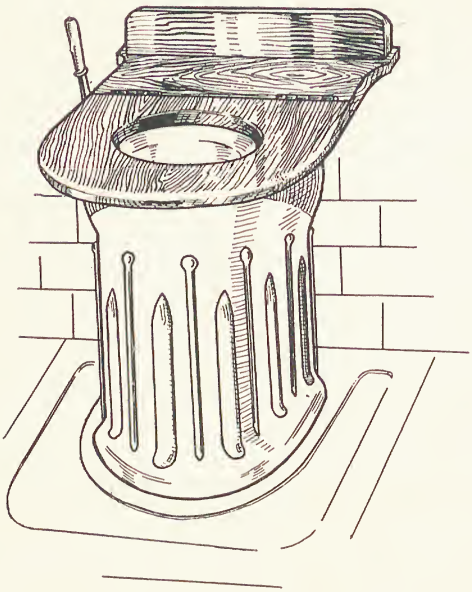


Fig. 6.—A MODERN TYPE OF PEDESTAL VALVE CLOSET

valve is governed by a regulator which is adjusted to the pressure of the water and the amount required to recharge the basin.

In the modern valve closet the basin, circular-fronted apron, and slop top are in one piece of glazed earthenware. All the mechanism is hidden behind this earthenware, so that the fitting presents the appearance of a pedestal closet.

It has also been brought up to date and simplified by the provision of a cast-iron or lead trap, fixed above the floor line, the cast-iron trap having a brass union for soldering with a wiped joint to the soil pipe.

Fitting Up and Fixing

The trap is first fitted in position, and the branch soil pipe fitted thereto and fixed. The mechanism is then fixed in position, the valve box vent pipe connected, and the water supply connected to the flushing valve. The basin and apron are then fixed, the joint between the basin and trap being made by a rubber ring and notched and screwed brass ring.

Modern valve closets are fitted with water valves regulated to pass a pre-arranged quantity of water, to overcome the objection that valve closets use more than 2 gal. of water at one flush, and to satisfy the demands of local water authorities.

Slop Sinks

As the name implies, the slop sink is a sanitary appliance used for the reception of household slops and washings, and as such is a soil fitment that must be connected to a soil pipe for discharge into the drain.

For the purpose of cleansing household utensils, hot- and cold-water taps are usually placed in a suitable position above the appliance. For cleansing and flushing the fitting itself, a siphonic flushing cistern is provided and connected by means of a flush pipe to the rim of the sink.

Where hot- and cold-water taps are placed above the sink, special attention should be given to the construction of the soil pipe. Owing to the expansion and contraction, buckling will occur in a lead soil or waste pipe subjected to alternate discharges of hot and cold water. For this reason lead should not be used, and preference be given to iron or copper.

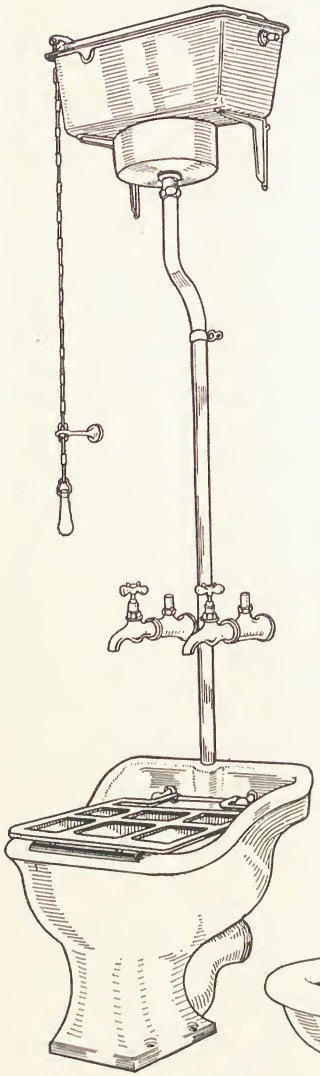
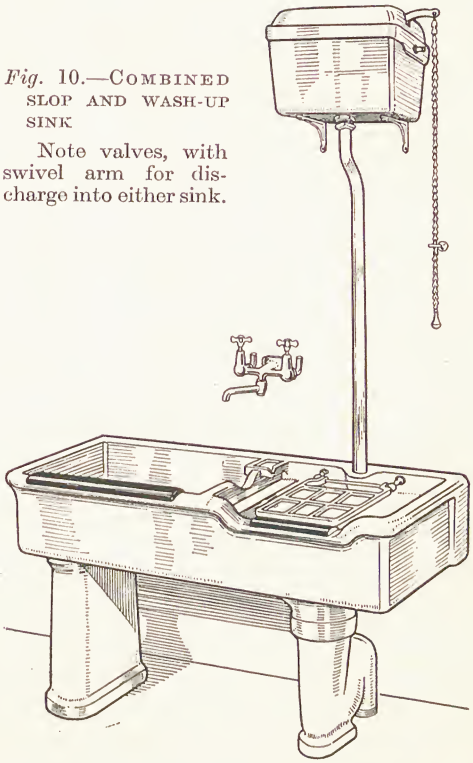


Fig. 7.—SLOP SINK, COMPLETE WITH HOT AND COLD VALVES AND FLUSHING CISTERN

With hot and cold taps placed above sink, preference should be given to soil pipe of copper or iron, rather than of lead.

Fig. 10.—COMBINED SLOP AND WASH-UP SINK

Note valves, with swivel arm for discharge into either sink.



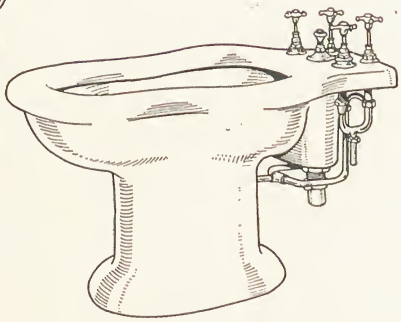


Fig. 8.—BIDET COMPLETE WITH CIRCULATING FLUSHING RIM AND SPRAY WITH SEPARATE HOT- AND COLD-WATER VALVES TO EACH

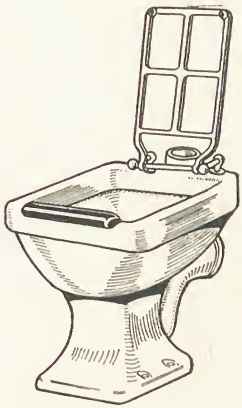


Fig. 9.—SLOP SINK OR HOPPER, SHOWING BRASS HINGED BUCKET GRATING AND HARDWOOD INSET

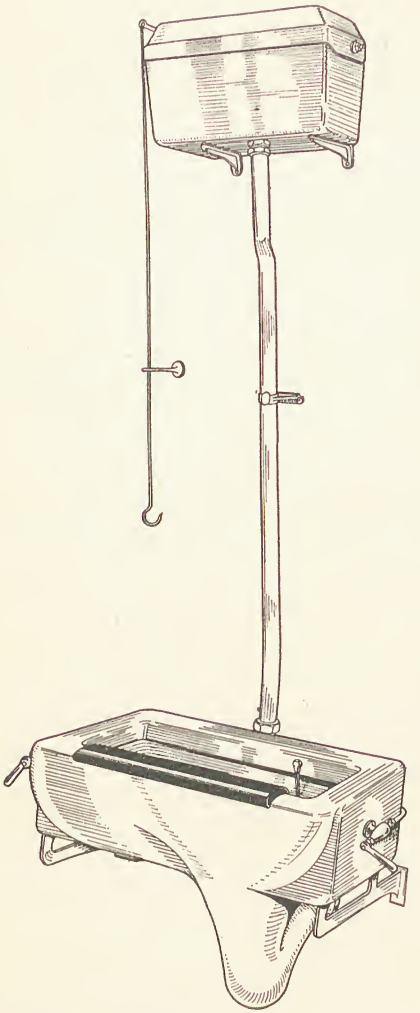


Fig. 11.—HOSPITAL BED-PAN SINK AND URINE-BOTTLE WASHER, SUPPORTED ON CANTILEVER BRACKETS

Slop sinks are similar in construction to a water-closet pan, that is to say, provided with a base so that the sink may be bedded and screwed down to the floor, or provided with slots to slip over iron cantilever brackets built into the wall, or constructed on the corbel principle, with extension lugs for building into the wall. The cantilever or corbel supports permit the sink to be fixed clear of the floor, thus giving free access for cleansing the surround and promoting hygienic conditions.

Hospital Bed-pan Sinks

These are as a rule constructed and arranged on the corbel principle for building into the wall, or to rest on cantilever brackets.

A water jet is provided in the bottom, over which bed-pans are laid for the purpose of cleansing after emptying, and also with a side jet for cleansing urine bottles. In order to exert a good scouring effect upon the utensils to be cleansed, the water supply to the jets should be under considerable pressure.

The valves to the jets may be arranged for foot, knee, or elbow operation, or they may have ordinary crutch heads for hand use. All the piping connected with hospital sinks should be nickel, chromium-plated, or white-enamelled.

A siphonic flushing cistern forms part of the equipment, and the sink is fitted with a flushing rim so that it may be cleansed after use, and tainted water removed from the trap.

Bed-pan sinks must be connected direct to a soil pipe, and the same conditions observed in the construction and the materials used for the soil pipe as with slop sinks.

Flushing Cisterns for Water-closets, Slop Sinks, etc.

Most water authorities insist on the installation of water waste-preventing flushing cisterns. The water content of these cisterns is emptied

or flushed into the sanitary appliance by siphonic action. There must be no valves in the cistern through which water could possibly flow and thus run to waste.

The quantity of water usually allowed by water authorities for flushing purposes is 2 gal., although in some parts of the country 3 gal. is allowed.

Water waste-preventing cisterns for flushing purposes may be obtained for fixing in one of two positions—at high or at low level, the latter being termed a low-down cistern.

The high-level cistern is fixed at a convenient height above the appliance to give ample head room, and on the back or side wall whichever is convenient from a structural point of view, or lends itself most favourably to the layout of the compartment.

A low-down cistern is fixed in conjunction with what is known as a low-down suite situated at the back of and about 15 in. above the water-closet.

Overflow

The overflow of the cistern should be large enough to take the full flow of the water entering through the valve. It must be fixed above the level of the siphon, but below the level of the ball valve, in order that the latter cannot become submerged. The overflow must discharge as a warning pipe, so that any waste of water can be easily detected.

Ball Valves

The ball valve should be of a type according to the water pressure it has to withstand, and be fitted with a silencing pipe drilled at the top to prevent the contents of the cistern siphoning back into the supply pipe in the event of the water supply being shut off and drained down.

Flush Pipes

Flush pipes may be constructed either of lead, copper, brass, galvanised mild steel, or white-enamelled steel. Copper or brass flush pipes may be nickel or chromium-plated, as befits the position.

The size of a flush pipe from a high-level cistern need seldom exceed $1\frac{1}{4}$ in. internal diameter. The use of a lead or copper flush pipe lends itself admirably, as either may be bent to any position determined by the position of the cistern, and further, a copper pipe may be bent and sent away for chromium-plating.

Too many bends in a flush pipe should be avoided, and bends that are made should be of the easy type. Too many and too sharp bends retard the flush.

Galvanised-steel telescopic flush pipes may be obtained bent to position, for use where the cistern is to be fixed on either the back or side wall.

Flush pipes for use with low-down suites are usually $1\frac{1}{2}$ in. in diameter,

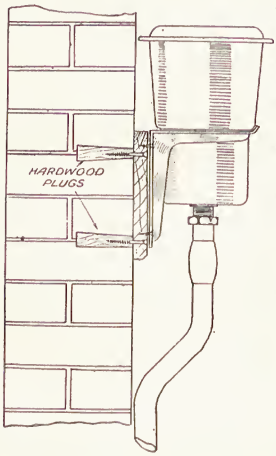


Fig. 12.—SHOWING BRACKET SCREWED TO BRACKET BOARD FOR FIXING FLUSHING CISTERN TO WALL

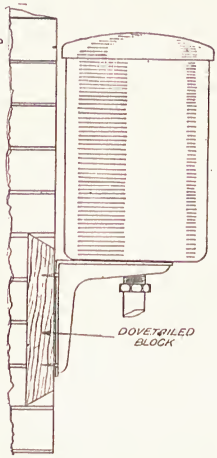


Fig. 13.—WASTE WATER PREVENTER SUPPORTED ON BRACKET SCREWED TO DOVETAILED BLOCK BUILT INTO WALL

to allow the flushing water to enter the pan with a sufficient force to adequately flush it. It will be understood that the water from a low-level cistern does not enter the pan with such force as from a high-level cistern, and therefore a larger quantity entering the pan at one time will counteract this by providing sufficient force to flush the pan.

The joint between the flush pipe and the pan may be made by means of one of the many patent joints made for the purpose, or by means of a lead star washer. The washer is cut out and placed on the pipe before it is fixed, a quantity of jointing material is placed between pipe and pan socket, and the clip secured to the socket by the points of the washer.

Fixing Flushing Cisterns

Cisterns are supported on brackets of types befitting the construction and material of the cistern. The fixing of the brackets depends on the type of cistern and on the type of job. In some cases, a bracket board is fixed to the wall by screws to wooden plugs or blocks let into the wall, and the cistern brackets are screwed to the board. In other cases, such as a tiled or glazed-brick surface, the wall is plugged with a hardwood or patent plug, and the bracket screwed flush to the wall. Cantilever brackets are also used.

URINALS

Design and Construction

Many defects common to the early types of urinal are eliminated in the best modern fixtures.

Probably the most important features in the design of a urinal are: that it should be so shaped to allow of the minimum area becoming fouled in use, and that the area so open to fouling is flushed with water.

Modern urinal stalls are usually constructed in one piece of glazed fire-clay, with the channel as an integral part, or in two pieces with a

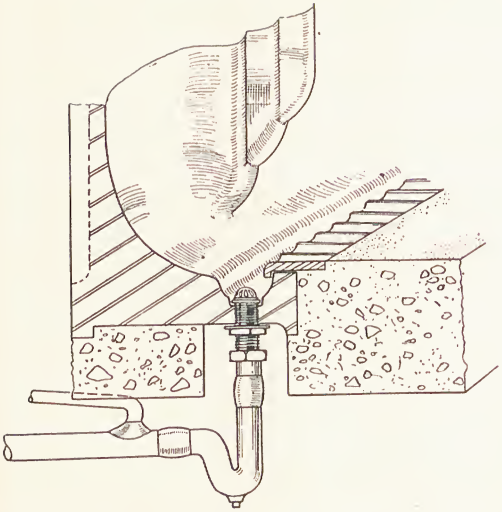


Fig. 14.—PART-SECTION OF URINAL STALL, SHOWING WASTE OUTLET WITH LEAD TRAP, WASTE AND VENT PIPES

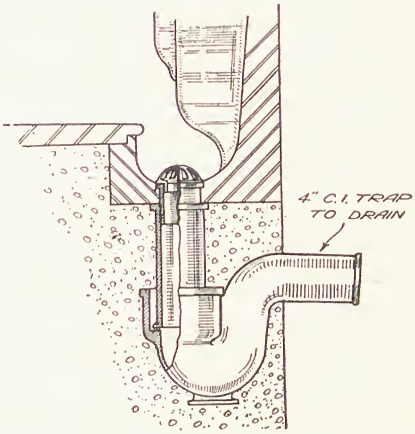


Fig. 15.—SECTION OF URINAL OUTLET AT GROUND FLOOR

separate channel. In each case the discharge from the urinal takes place through an outlet formed in the channel portion.

The stalls are constructed so that they may be fixed singly, in pairs, or in ranges. The number of stalls required will depend on the type of building, its occupants, and the accommodation necessary for use at one time. The installation of one or two urinal stalls on each floor in connection with the sanitary arrangements of, say, an office building, will provide great convenience and prevent the undue fouling of water-closets.

Fixing on Concrete Floors

When urinal stalls of the type shown in Fig. 14 are to be fixed on concrete floors, two methods may be adopted.

In the first case, the stalls are fitted at floor level, and a step is formed in the front to receive the treads, as shown in Fig. 18 for treatment on a wood floor. The second method is used where it is desired to keep the tread flush with the floor, as shown in Fig. 14, and in this case it is necessary to form a sinking in the construction of the floor to receive the base of the urinal stall, and for the floor to have a slight fall to the channel.

Where Thickness of Floor Is Insufficient

In the case of a floor being of insufficient thickness to accommodate pipes, etc., and full-length stalls are desired, the difficulty may be overcome by the use of stalls having individual outlets discharging into a channel sunk in the floor (Fig. 16).

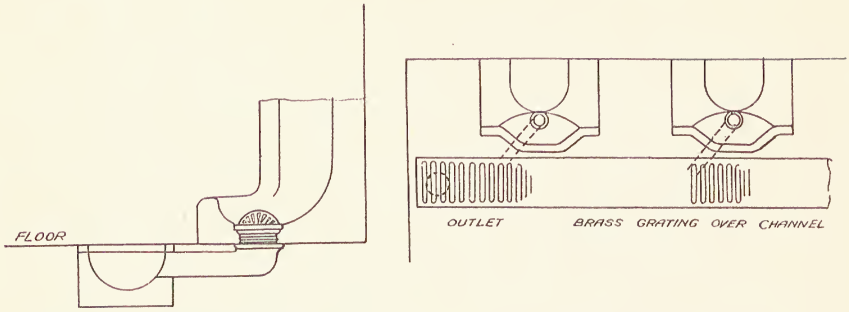


Fig. 16.—"SHANKS" URINAL STALLS WITH INDIVIDUAL OUTLETS DISCHARGING INTO CHANNEL IN FLOOR

Suitable for positions where thickness of floor will not accommodate traps, waste pipes, etc.

Fixing above Floor

If desired, stalls may be obtained for fixing clear of the floor, and a section of this type is shown in Fig. 17. Each stall is provided with a separate trap discharging into a main waste pipe. These may be obtained in white-glazed fire-clay, with backs and dividing pieces in marble or granite.

Fixing on Wood Floors

When stalls of full length are to be fixed on wood floors, an impervious covering should be laid before they are fixed. This covering should extend well beyond the space occupied by the stalls, and if the apartment is of small area the whole of the floor should be covered. Without this protection, there is great risk of moisture finding its way into the floor, thus creating a nuisance and causing damage (Fig. 18).

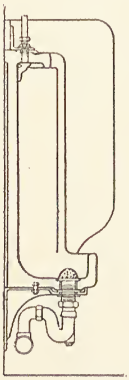


Fig. 17.—URINAL STALL WITH TRAP AND WASTE PIPE FIXED CLEAR OF FLOOR (*Shanks*)

Joints

The joints should be well grouted with Portland cement, and the treads, which are designed to lip over on to the channel, should be carefully bedded and jointed in the same material. Unless care is taken with the latter item, moisture from splashings and washings may seep through the joints, causing trouble from dampness and odour.

The Urinal Outlet

The urinal outlet must be provided with a brass domical grating and outlet connection. If the urinal itself is fitted on a ground floor, the outlet can be arranged to fit over a trap of earthenware or cast iron, according to the

construction of the drains (Fig. 15).

When fitted on an upper floor, the urinal should discharge into a lead trap, joined to the brass outlet connection with a wiped soldered joint, and being so arranged that the cleaning-screw of the trap is accessible from the floor below, as in Fig. 14.

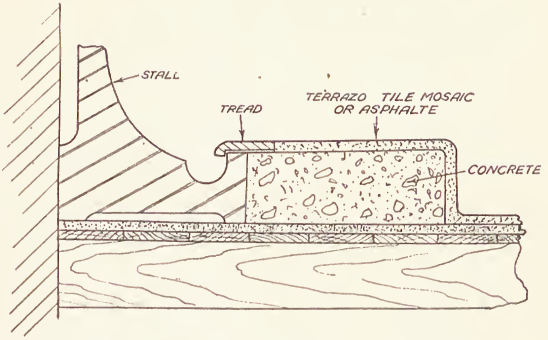


Fig. 18.—Treatment of urinal on wooden floor

The brass domical grating fitted in the outlet should be removable for clearing purposes.

Flushing Arrangements

The urinal stall or stalls must be fitted with an automatic flushing cistern of ample capacity, and a flush pipe divided to discharge into each stall.

The capacity of the flushing cistern will depend on the number of stalls. The actual amount of water discharged into each stall should be sufficient to cleanse the surface, the time between each flush being governed by the amount of use to which the urinal is put. The supply of water to the cistern may be regulated by a reverse-action ball valve, or by a drip valve regulated by a screw.

THE BIDET

In most Continental countries, and in America, the bidet is a sanitary appliance that is considered a necessary addition to the modern bathroom. In this country the bidet is little used, perhaps mainly on account of the ignorance of its purpose.

Use of the bidet ensures personal cleanliness to those parts of the body that cannot be comfortably cleansed in any other way, and is useful also for the treatment of various ailments.

The bidet is constructed of white or coloured glazed ware, and is in the form of a pedestal with a flushing rim. An ascending spray nozzle is usually fitted in the bottom of the basin but may be omitted if desired. Hot and cold supply valves (two or four) are provided to control the supplies to the rim and spray. In those having four valves, separate control is maintained to rim and spray respectively (Fig. 8).

A mixing fitting or box may also be provided to enable the user to control the admixture of hot and cold water for the rim or spray.

Like lavatory basins, the bidet must be provided with an overflow,

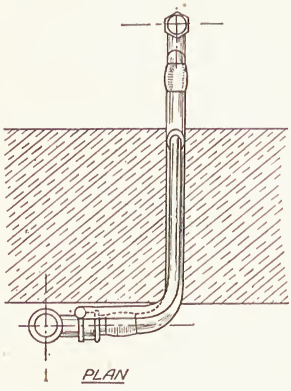


Fig. 19.—BIDET FITTING

Showing arrangement of waste pipe with lead trap, cast-iron main waste, and lead trap ventilation pipe.

Note.—If fittings at higher floors are to be connected to the main waste pipe, the lead vent should be taken to the right as indicated by dotted lines. This is to avoid crossing the waste branch above (also indicated by dotted lines). Crossing pipes should always be avoided.

and this is usually an integral part of the basin ; it should be accessible for cleaning purposes.

This may be of the ordinary plug and chain type ; the combined standing waste and overflow pattern ; or of the pop-up variety operated by a lever with a knob attachment. The outlet may be provided with a plain union for connecting to a lead trap, or with a brass trap with cleaning screw and union for connecting the trap ventilation pipe.

According to modern by-laws, the bidet is a waste-water fitment, and as such must be connected to a waste pipe for discharge into a properly trapped gully.

Joints

The joints to outlet union or brass trap, supply valves, etc., should be of the wiped soldered type if the pipes are of lead. If copper waste and supply pipes are used, the joints should be of approved type.

The pedestal is fixed to the floor by screws passed through holes provided in the base in a similar way to that adopted for fixing an ordinary water-closet pedestal basin.

WATER HEATING BY GAS

THE problem of hot-water supply differs from other domestic services in the fact that there are so many variable factors which affect the choice of a system that will satisfactorily meet the requirements of any particular installation.

If a number of houses of similar type were selected at random, it would be found, for example, that there is considerable variation in the hot-water requirements of each, due to the personal habits of the occupants, the number of persons in the house, the extent of the family purse, and so on.

During recent years the gas industry has successfully met the problem of domestic and other hot-water supply by designing a range of water heaters of such types and sizes that any possible requirements can be catered for adequately. Tariff schemes and similar promotional schemes of charging for gas are now becoming generally adopted, and, coupled with the economies effected by convenience and saving of labour, bring the cost of water heating to a figure comparable with and often cheaper than the solid-fuel boiler.

In normal domestic work, where running costs affect the selection, and the choice rests between a solid-fuel boiler and a gas heater for the hot-water supply, the value of combining the services that can be obtained from each of these two methods should be given consideration. For domestic demands, the dual system provides the most acceptable means of providing a flexible hot-water supply system. It will, with very little extra cost for its use in summer, provide copiously in winter and sufficiently in summer, the latter a time when the discomforts of having the coke boiler in use can be eliminated without detriment to the service of hot water for the household.

Types of Gas Water Heater Available

Broadly speaking, gas water heating may be accomplished by either of two methods :—

(1) Instantaneous.

(2) Storage.

These two methods may be briefly described as follows :—

(1) *Instantaneous Gas Water Heaters*

The water flowing to the required point is heated while it is actually flowing from the cold supply to the point. For this reason, instantaneous types of heater are sometimes referred to as " throughput " heaters.

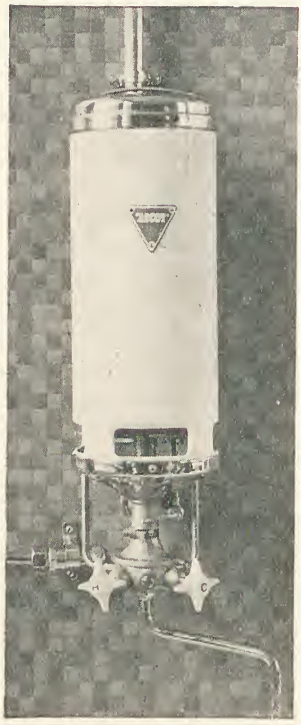


Fig. 1.—A SINGLE-POINT INSTANTANEOUS GAS WATER HEATER

As will be seen later, many ingenious types are available for both single-point and complete multi-point supply.

(2) *Storage Gas Water Heaters*

With this class (of which, again, there are many types) water is heated and stored in an insulated tank or cylinder, and released as required at the draw-off taps.

INSTANTANEOUS GAS WATER HEATERS

Modern instantaneous gas water heaters are of four types :—

The single-point sink heater.
The multi-point sink heater.
The single-point bath heater.
The multi-point heater.

All heaters are essentially automatic in operation. The action of turning on the hot-water tap is all that is needed for the user to obtain his requirements. Automatic valves give almost silent ignition, and devices are incorporated to close off the main gas supply to the burner should the pilot jet become extinguished by accident, or because of the temporary lapse of the gas supply on slot-meter installations.

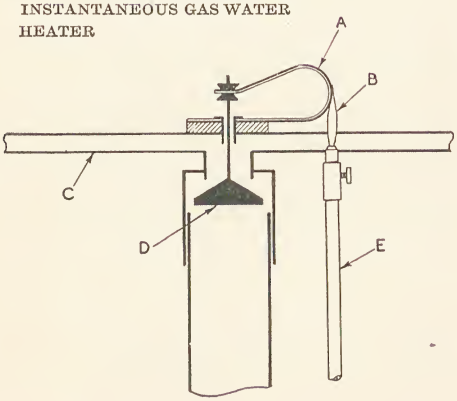


Fig. 1A.—A TYPICAL SAFETY CUT-OFF—AS FITTED TO THE "ASCOT" WATER HEATER

The bimetal strip A is heated by the flame, B, from the pilot tube E. Heat causes the strip to bend and keep the main gas valve, D, open to allow gas to pass to the burner, C. If gas be extinguished, the strip, A, cools and closes valve.

Deciding Whether to Connect to Main Water Supply or to Tank

Water pressure is the medium upon which the valves of the heaters depend for their operation. Although it is normally permissible to fit any of these domestic heaters direct to the main supply, the decision rests with the local water authority, and is governed by their particular regulations. This point of fixing, however, should be confirmed by communication with the local representative of the water authority. Fixing to main water supply usually provides an adequate water pressure, but is accompanied

by the disadvantage of fluctuations in pressure. This fact leads to fluctuating results in the hot-water supply, and possibly, because of the sensitiveness of valve mechanism, to the entire failure of the valve to function due to the water flow becoming lessened to below the safe minimum rate.

Where it is practicable, and a sufficient head of water can be obtained, it is preferable to provide for a storage tank to be the source of the cold feed to any heater. Steady water pressure ensures a regular operation of valves and a constant supply of hot water, with its temperature under the hand of the user by the control of the hot-water tap.

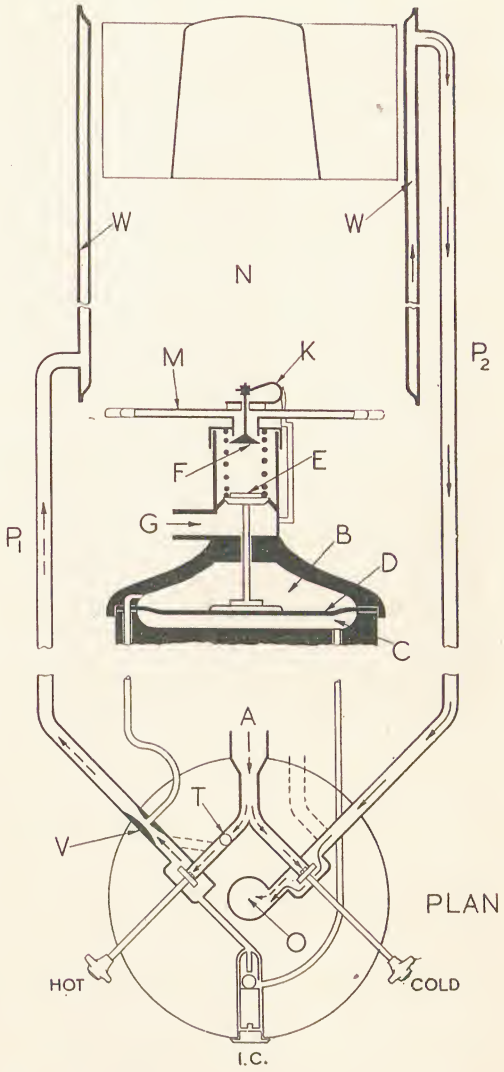


Fig. 2.—DIAGRAM ILLUSTRATING THE OPERATION OF A WATER-PRESSURE OPERATED GAS HEATER OF THE INSTANTANEOUS TYPE

Hot, cold, or mixed water may be obtained at will.

Flue Equipment Required

Excepting the single-point sink heater, it is customary to have all instantaneous water heaters ventilated with flue equipment comprising primary flue-pipe, baffler, secondary flue-pipe, and a terminal. Most designs of modern heater include, as an integral part of the appliance, the primary flue and the baffler. With such appliances, of course, the flue equipment needed is only the secondary flue-pipe to the outside air, and the terminal.

The position in which the terminal is fitted is very important. Two types of terminal are available which fulfil the requirements of all situations. The louvre type, for upright fixing to vertical flue-pipe, is one ; the " Ventile," for fixing to flue-pipe necessarily terminating in a horizontal position, is the other. Various methods of install-

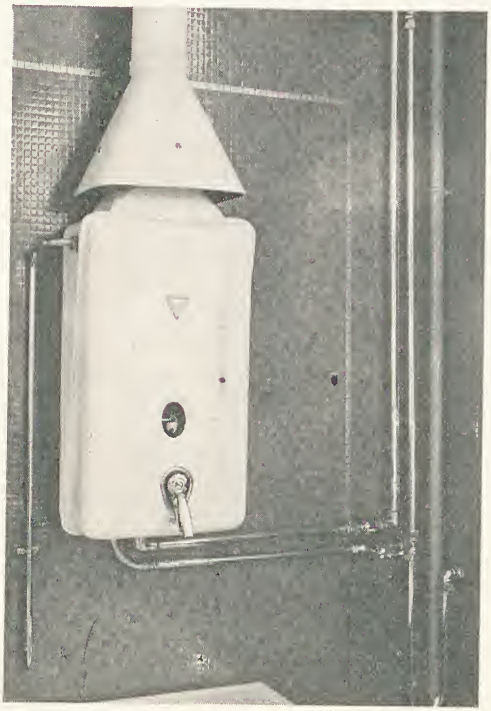


Fig. 3.—A MULTI-POINT INSTANTANEOUS GAS WATER HEATER ("ASCOT")

ing flues are illustrated on page 203.

The correct location for the louvre type is in a well-exposed position above the eaves. If there is likelihood of any position being susceptible to the forming of air pockets due to adjoining buildings, the flue-pipe should be extended for the terminal to be installed outside the static area. The terminal is designed to augment ventilation in high winds, and the practice of finding a sheltered spot close under the eaves nullifies this purpose, is bad practice, and is a method to ensure negative results.

Many occasions arise where the exit for flue-pipe is to be unavoidably situated comparatively low on the building face. If the position is clear of obstructions, e.g. soil and drain pipes, cills, wall buttresses, etc., the "Ventile" or wall terminal is the fitting that should be used in such circumstances. It is the best practical method to adopt; it is the cheapest method; it is preferable to the unsightly projection of the commonly used elbow and upright terminal.

Do not use Brick Flue with Instantaneous Heaters

An inconvenient location relating to the nearest outside wall may lead to the consideration of ventilating an instantaneous water heater into a brick flue, or a flue built specially for the purpose with flue blocks. This practice, particularly the latter, should be avoided wherever an alternative path for the flue can be found. If no alternative path is available, then another position for the heater should be sought.

Instantaneous water heaters have a high rate of gas consumption and, to give the highest possible efficiency with reasonable life, the air dilution of the products of combustion is kept to a minimum. Coupled with the fact that the heaters are used intermittently, which means that the products would nearly always enter a cold flue, heavy condensation is unavoidable in a brick chimney.

Automatic Valves—Construction and Operation

Instantaneous water heaters are produced by many makers, but the method of obtaining automatic operation is fundamentally similar on all types. To describe all types that are available is therefore unnecessary, if a typical example can be given to include the principles that are generally adopted.

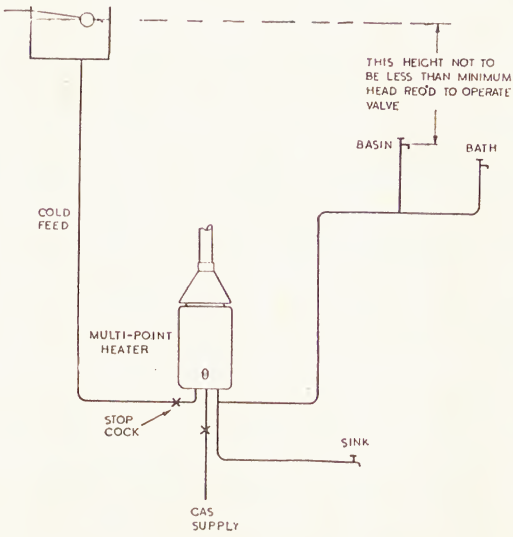


Fig. 3A.—TYPICAL INSTALLATION OF A MULTI-POINT GAS WATER HEATER TO SUPPLY ALL HOT TAPS IN A SMALL HOUSE

The heater comes into operation automatically immediately one of the hot taps is opened.

Single-point Sink Water Heaters

The composite line diagram shown in Fig. 2 gives in a simple way the construction of a typical sink water heater. It is common to most forms of this type of heater to have control taps to provide hot or cold water. By using them together any degree of mixing can be obtained. For clarity, therefore, to show the water passages and controls, the base of the valve, i.e. below the diaphragm, is given in plan. The remainder of the heater, the gas controls, combustion chamber, and water chamber, are given in vertical section.

The Path of the Water through the Heater

Water enters at the inlet connection A. If the cold-water tap, C, is opened, the water flows directly to the outlet, O, in the centre of the base of the valve. If the hot-water tap, H, is opened, cold water flows by the throttle, T, which controls the water rate from the heater, through the tap valve, through the venturi, V, up the connecting stand pipe, P_1, and into the water chamber or coil, W, around the gas combustion chamber. The heated water returns down the connecting stand pipe, P_2, and issues from the outlet, O. It can be seen from the diagram how mixed water is obtained by the use of both taps, hot and cold, together.

The rubber diaphragm, D, is totally enclosed in the water chamber, B. The sections on each side of the diaphragm are connected to the inlet water ways when the hot tap is opened. The top section is directly connected to the throat of the venturi, V ; the bottom section is connected via the ignition control device, IC.

The effect of these connections is to give a delayed action to the open-

Fig. 4.—LARGE STORAGE HEATER—CAPACITY 40 GAL. AT 140° FAHR.

ing of the gas valve, and so enable ignition to be kept almost silent due to the gradual release of the gas to the burner.

The water flowing through the venturi, V, creates a suction on the connecting tube to the top section of the diaphragm chamber, and thereby lessens the pressure there. The under side of the diaphragm is simultaneously subjected to pressure, and thus is given an initial or " opening " lift. This is immediately followed by the gradual effect of the water at full working water pressure entering the lower section of the diaphragm chamber, at a rate controlled by the ignition device, to complete the lift of the diaphragm to open fully the gas valve. The dotted lines on the diagram show the additional waterways to provide for multi-point supply.

The Gas

The gas enters at the inlet G. It passes first through the main valve, E, then by the valve, F, of the safety device, K, and so to the burner, M, where it is ignited by the pilot jet shown. A gas rate control is normally fitted to the inlet. The products of combustion ascend the combustion chamber, N, pass around the baffle and heat interchanging fins, and then leave at the flue exit.

The Safety Device, or Thermo-cut-off

The safety device is fitted as a precautionary measure against the extinguishing of the pilot jet.

An enlarged sketch of this item is given in Fig. 1A. The valve of the thermo-cut-off is suspended in the main gasway from the free end of a bimetallic strip folded in the form of a horseshoe. The other end is rigidly attached on to the burner frame.

In operation the pilot jet continuously plays on the crown of the bimetal loop. The unequal extension of the metals of which the strip is made—usually brass and steel—causes the free end carrying the valve to

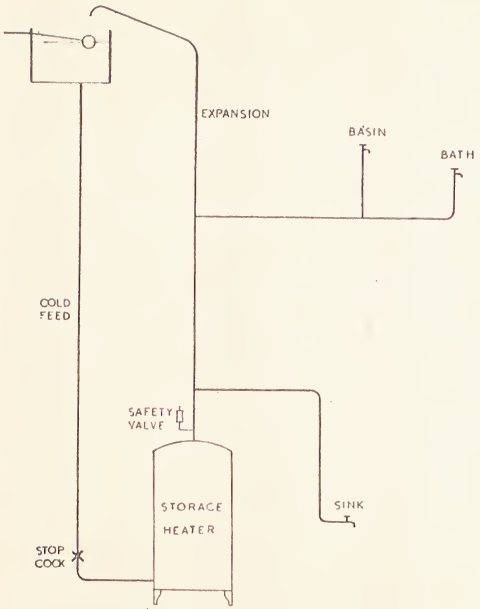


Fig. 4A.—METHOD OF CONNECTING A STORAGE HEATER TO SUPPLY THREE HOT-WATER TAPS IN A SMALL HOUSE

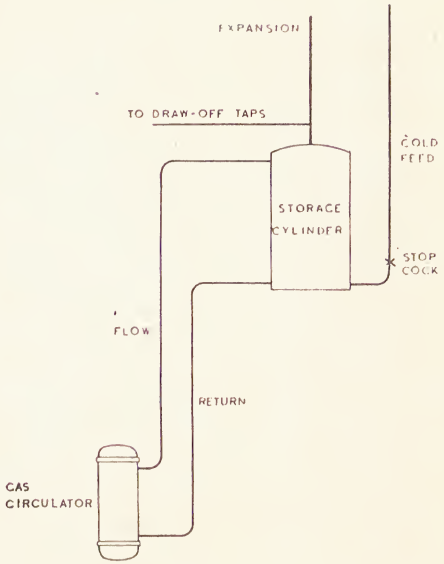


Fig. 5.—GAS CIRCULATOR FITTED TO HEAT CONTENTS OF HOT-WATER STORAGE CYLINDER

be depressed, and so to maintain the gasway open. If the pilot jet is extinguished, for any reason, the bimetal strip cools, the free end resumes its normal horizontal position, pulling the valve on to its seating. From that moment no gas will be available at the burner until the bimetal strip has been reheated by the pilot jet.

Multi-point Heaters

In principle of operation this type of heater is exactly similar to the single-point sink heater described. The gas valve is opened by the lift of a diaphragm operated by a differential water pressure. The gas is ignited by a pilot jet which controls a safety cut-off device. Water throttle, gas rate control, and ignition device are now all standard components of modern heaters.

In construction, however, there is the essential difference that the multi-point heaters have water coils fitted that are strong enough to withstand the full working pressure of the water supply, particularly where the heaters may be fitted to main supply.

Many instances occur where single-point sink heaters have been fitted to feed two or more hand basins. The closing of the outlet in this manner has resulted in many cases of burst water chambers, due to the high water pressures which the single-point type of heater is not constructed

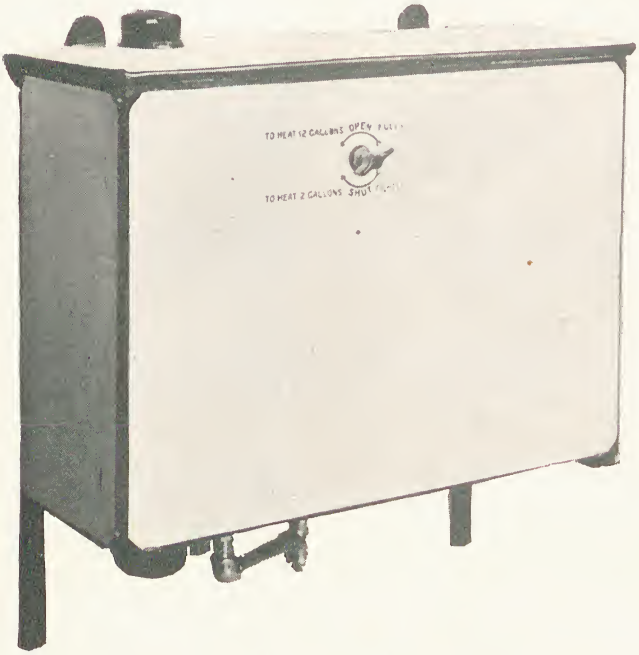


Fig. 6.—SMALL WALL TYPE STORAGE HEATER TO SUPPLY 2 OR 12 GAL. AS REQUIRED

to withstand. Multi-point sink heaters are available for such work. A typical method of installing a multi-point heater in a small house is shown in Fig. 3A.

Single-point Bath Heaters

Modern single-point bath heaters, like the multi-point heaters, are fully automatic in operation.

Many types of automatic valves are fitted to the bath heater, although all are of much simpler design than those fitted to multi-point appliances. They all function upon the opening of the inlet water control tap.

For normal water pressures the various valves function by differential water pressure, direct water pressure, and by suction induced by water flow. These types effect the opening of the gas valve through the medium of a rubber diaphragm. Another type, for very low water pressures (down to 6 in. water head), depends upon float chambers directly connected with the gas valve. The inflowing water lifts the float and thus the gas valve. Also, for low water pressure, the type of valve known as the " bucket " valve is used. A perforated bucket is attached to one end of a centrally pivoted fulcrum arm, and is positioned beneath the inlet water spout. To the opposite end of the arm is attached the connecting rod to the gas valve. The inflowing water weights the bucket, which drops, to open the gas valve.

Output from Instantaneous Water Heaters

The rated output of all instantaneous water heaters is given as " gallons of water raised 40° F." This nominal figure should not be taken as the inflexible output from the appliances, but only as a guide to performance.

Water heaters are now designed to pass, at the minimum, a water flow

that will give a maximum temperature rise of 100° F. Since the water rate from any heater varies with the temperature rise it is quite simple to calculate the temperature rise that will accompany any given water rate and, vice versa, for any desired temperature rise the water rate can be found.

Example

Nominal output of heater $= 2\frac{1}{2}$ gal. per min. raised 40° F.

Temperature rise with water rate at $1\frac{1}{4}$ gal. per min.

$$= 40° \text{ F.} \times \frac{2\frac{1}{2}}{1\frac{1}{4}} = 80° \text{ F.}$$

Water rate given when temperature rise of 100° F. is needed

$$= 2\frac{1}{2} \times \frac{40}{100} = 1 \text{ gal. per min.}$$

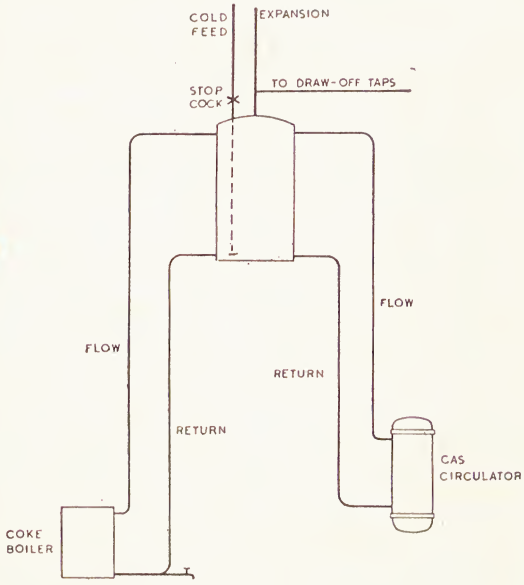


Fig. 6A.—A GOOD METHOD OF UTILISING A GAS CIRCULATOR TO ACT AS A BOOSTER TO, OR AS AN ALTERNATIVE TO, AN EXISTING COKE OR OTHER SOLID-FUEL BOILER

TABLE OF SIZES OF DOMESTIC INSTANTANEOUS WATER HEATERS AVAILABLE

Type	*Gas Rate* (500 *C.V.*) *in Cu. Ft. per Hour*	*Nominal Output Gal./Min. Raised* 40° *F.*
Single-point sink heaters	60	1
Multi-point sink heaters	90	$1\frac{1}{2}$
Single-point bath heaters	120	2
	150	$2\frac{1}{2}$
	180	3
	195	$3\frac{1}{4}$
Multi-point heaters	150	$2\frac{1}{2}$
	180	3
	210	$3\frac{1}{2}$

STORAGE WATER HEATERS

Storage water heaters are self-contained appliances. The heating unit is fitted either at the side, or concentrically in the base of the storage

tank. From the heating unit the heated water ascends an internal flow pipe into the storage tank, where it is maintained hot until it is required. The normal temperature setting of the thermostat on storage heaters is 140° F. A typical method of connecting a storage heater is shown in Fig. 4A.

The heaters vary in capacities and gas rates over a very wide range. The capacities extend from 2 gal. up to 40 gal., and the gas rates from 10 cu. ft. per hour to 95 cu. ft. per hour. The recovery rate of any heater depends upon its gas rate. The heater with the lowest gas rate—10 cu. ft. per hour—has a recovery rate of 4 gal. per hour raised 100° F., and this serves as a good basic figure to calculate the output from other sizes; e.g. a heater with a gas rate of 95 cu. ft. per hour will give an hourly output of (9·5 × 4) = 38 gal. of water raised 100° F.

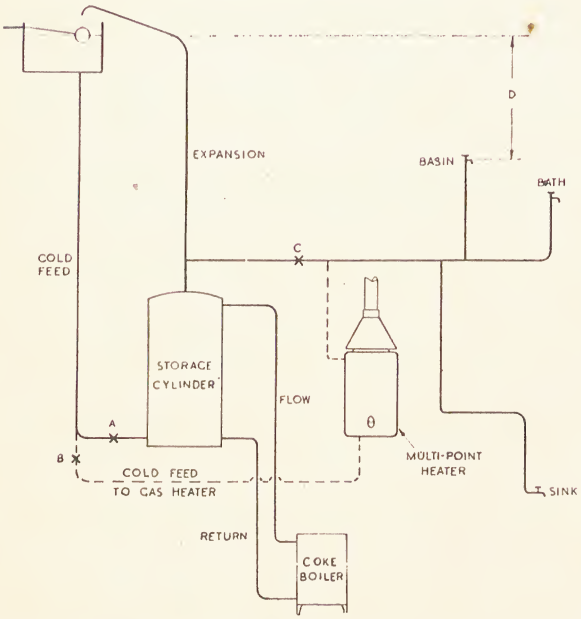


Fig. 7.—A MULTI-POINT GAS HEATER INSTALLED FOR USE AS AN ALTERNATIVE, AS REQUIRED, TO A COKE BOILER OR RANGE

Additional pipe work is shown dotted. To bring the gas heater into use, valve B is opened and valve C is closed. When coke boiler is in use valve B is closed and valve C is opened. Valve A is used only to shut down boiler system for maintenance.

Sink Storage Water Heaters

Small storage heaters, for use at kitchen sink or hand basin, with capacities of about 2 gal., are equally as suitable as the instantaneous sink heaters. They also have the advantage of thermostatic control, and so provide a constant outlet temperature regardless of any change in inlet water temperature. This fact makes the storage sink heater of particular value for installation in the surgeries of doctors, dentists, etc. One type has an adjustable graduated thermostat for giving any temperature at the outlet between 110° F. and 180° F.

Storage Water Heaters for Wall Fixing

The smallest of the large heaters is of about 12 gal. capacity and, where floor space is not available, this size can be fitted to a wall. The wall, of

course, must be stout enough to carry the heater, which, when full of water, weighs about 300 lb. Makers supply complementary brackets for the fitting of the heater in this way.

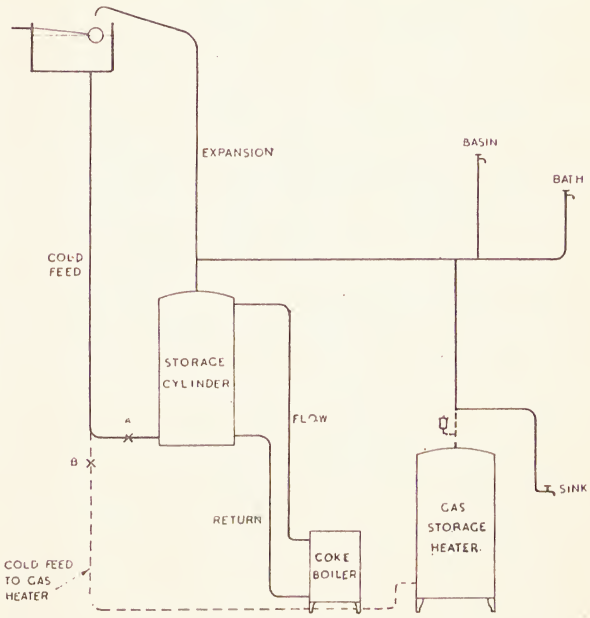


Fig. 8.—A GAS STORAGE HEATER FITTED FOR USE AS AN ALTERNATIVE TO A RANGE OR COKE BOILER

New pipe work required is shown by dotted lines. To use the coke boiler, valve B is closed and valve A is opened. When the gas storage heater is required, valve A is closed and B is opened. For heavy duty both heaters may be used at the same time.

TABLE OF STORAGE WATER HEATERS AVAILABLE

Type	*Gas Rate Cu. Ft. per Hour*	*Capacity of Storage Gallons*	*Recovery Rate Gal./Hr. Raised 100° F.*
Low Consumption . .	10	12	4
	10	20	4
	10	30	4
	10	40	4
Medium Consumption . .	25	12	10
	25	20	10
	25	30	10
	25	40	10
	30	18	12
	40	25	16
	55	13	22
	55	18	22
High Consumption . .	80	38	32
	95	25	38
			Time to Fill with Hot Water at 100° F.
Sink Types	12	2	25 min.
	18	1½	12½ min.

Circulator Units

This type of gas heater can be used in many ways to cope with hot water demand. It can be directly connected to a storage tank as an independent unit—as shown in Fig. 5, or it can be fitted to an existing coke boiler hot-water system to work alternatively to or in conjunction with it. The scope of the hot water demand with which the circulator unit can deal is very extensive, as two or more of the units can be connected in parallel to fulfil any requirements.

The output of circulators is comparable with the storage heaters mentioned, but for a very much lower capital outlay an existing storage tank can be made use of to give exactly similar results.

TABLE OF GAS CIRCULATORS SHOWING TYPICAL GAS RATES

	Gas Rate Cu. Ft./Hr.	*Output. Gal. Raised* 100° *F./Hr.*
Low Consumption	10	4
Medium Consumption	25 30	10 12
High Consumption	60 80	24 32

Using the Gas Heater in Conjunction with the Solid-fuel Boiler

The types of gas heater that can be used in conjunction with a coke boiler are the circulator unit, the multi-point heater, and the storage heater.

The Circulator Unit

For providing an alternative hot-water service comparable with that given by the coke boiler, the circulator is the best unit to adopt. Floor space is not absolutely necessary, a minimum of pipe work is required for its installation, and the initial cost is lower.

There are various methods of fixing a circulator to an existing installation, but independent flow and return pipes directly connected to storage tank, as shown in Fig. 6A, are the best method. So fixed, intercirculation is positively avoided and best results are obtained.

The Multi-point Heater

To install a multi-point heater as an alternative method for hot-water supply requires a little more consideration. The multi-point has a limited output, and the existing pipework must be so installed as to conform to the operating requirements of the automatic valve. The highest draw-off must have a sufficient operating head and, on long runs to high draw-offs, the pipe sizes must be adequate—not less than $\frac{3}{4}$ in. By the

use of suitably positioned valves the coke-boiler system must be isolated from the supplies fed by the multi-point. A separate cold feed to the gas heater is desirable and, of course, flue equipment is definitely necessary. A typical arrangement is shown in Fig. 7.

The Storage Heater

Providing floor space can be found, and the comparatively high initial cost is not objected to, the installation of a storage heater to give an alternative hot-water supply is quite simple.

From the existing cold feed an extension is taken to the heater, and the expansion from the heater is connected into the existing draw-off supplies (Fig. 8). The existing expansion pipe must be left open to the gas-heated system.

Lagging

To minimise the running costs of gas-heated installations, lagging must be used. The saving in heat losses by lagging a gas installation is sufficient to repay the initial cost of the material and work in a very short time. It is particularly important where a circulator is functioning. On such gas-fired installations, the flow pipe, return pipe, the storage tank, and some of the expansion pipe should be lagged.

To emphasise the value of this desirable practice a Table of comparative heat losses between lagged and unlagged pipes and tank surfaces is appended.

TABLE OF COMPARATIVE HEAT LOSSES
BETWEEN LAGGED AND UNLAGGED PIPES

Size of Pipe	*Heat Losses per Hour/10-ft. Run in B.Th.U.*		*Saving in B.Th.U.*	*Saving per Week per 10-ft. Run (8·6d. Therm) (75% Effcy.) in Pence*
	Unlagged	*Lagged*		
½ in. . . .	470	100	370	7
¾ in. . . .	520	115	405	8
1 in. . . .	660	135	525	10
1½ in. . . .	900	170	730	14
2 in. . . .	1120	205	915	17
Galvanised tank per 10 sq. ft. . .	1200	220	980	19

SANITARY SURVEYING

PART V.—WATER SUPPLY

SO long as water is obtainable from the tap, the user does not concern himself as to the condition of the storage from which it is drawn; the tank is, therefore, rarely examined or cleansed. The general condition of the ordinary house storage tank leaves much to be desired. The tank is invariably fixed within the roof, and in many cases left uncovered, which renders it liable to pollution. Birds find their way into the roof space through defects in the under-eaves, and obtain their water from the tank, sometimes with fatal results to them. Mice and spiders are sometimes found there in a decomposed condition, while dust, with its harmful bane, finds easy ingress.

Storage Tanks

In the older type of houses, very large, lead-lined, shallow tanks were installed, and frequently fixed in a false ceiling over the bathroom, and would in consequence be accessible only from the upper bedroom floor, and subject to floor-washing abuses should the cover not be waterproof. In most districts, by-laws made under the Public Health Acts are enforceable, and require the householder to cleanse the storage tank at least once every six months, and for the tank to be fitted with a dustproof cover (Fig. 1). If fixed outside the house, i.e. on the roof, the cover must be weatherproof.

Intermittent Supply

It must be remembered that prior to the " constant " supply which we enjoy to-day, the " intermittent " supply of water was in vogue, and gave a supply from the main for only one or two hours per day, which necessitated a large storage tank or several tanks in accordance with the needs of the household.

Drinking-water Taps

Prior to the Public Health (London) Act, 1936, a main supply for drinking purposes was not enforceable; but recent legislation has now made this essential provision possible, so far as London is concerned. It is a step in the right direction from a health point of view, and will, no doubt, eventually be enforced in any district where a " constant " supply of water is installed. In carrying out a survey on old town houses it is

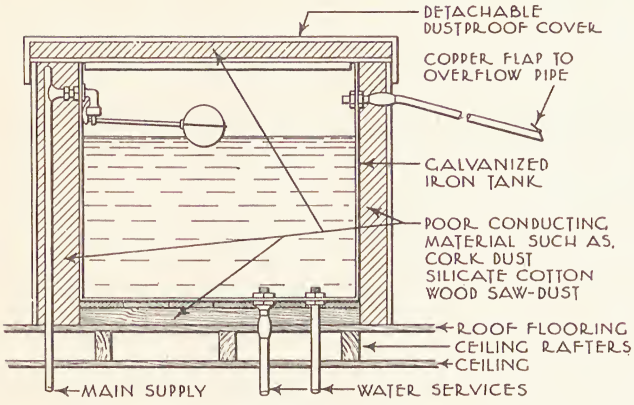


Fig. 1.—STORAGE TANK ENCASED IN ¾-IN. MATCHING, PROVIDING A 4-IN. TO 6-IN. CAVITY FOR INSULATING MATERIAL

necessary, therefore, to ascertain the source and adequacy of the supplies, the condition of the storage, and whether drinking-water taps are provided on the bedroom floor (lavatory basins are suitable places), and at the kitchen and scullery sinks.

Water from Well

Should the survey be in connection with a country house, where the supply of water is from a well, examination should be made of the storage and also the pumping gear, whether it be a lift and force pump, semi-rotary, or a jack-pump, and a sample of the water should be taken for analysis.

Analyst's Report, and Action Taken

If the analyst's report indicates sewage pollution, the source must be traced. Possibly it arises from a leaky cess-pool or its overflow, or from a farmyard manure heap. To obviate the nuisance, it may be necessary to recommend the sinking of a new well; and providing the site is on sloping ground, the position selected should be above that used for the cess-pool, and as far above as practicable. If the site is such that a new well is impracticable, then the alternative is to reconstruct the existing one by rendering it watertight to a position below the "plane of saturation," thus excluding surface and subsoil pollution.

Lining Well

This can be carried out by lining the well with concrete pipes backed up with well-puddled clay, allowing the water to enter the well only from the bottom portion (Fig. 2). The older type of well is found to be constructed of loose bricks, which permit water to find its way through at various levels, thus making pollution possible.

Water from Stream or River

The source of water may be from a stream or river, with a hydraulic ram as a means of acquiring it. Attention should be given to the ram to see if it is efficient, and to the treatment of the water before use, i.e.

whether some form of filtration or chlorination is applied to render the water fit for drinking purposes. The analyst's report will certify as to its purity.

Artesian or Deep-bore Well

The water supply to large blocks of modern flats in London has of recent years been drawn from the water-bearing stratum, consisting of chalk, which lies below the impervious stratum some 500 ft. below ground level, and the hydraulic pressure at this depth forces the water upwards within the bore tube to a plane of saturation which varies from 100 to 200 ft. from the surface. A smaller-diameter tube is installed within the bore tube, and the water is either drawn or forced through it and discharged into the storage tank.

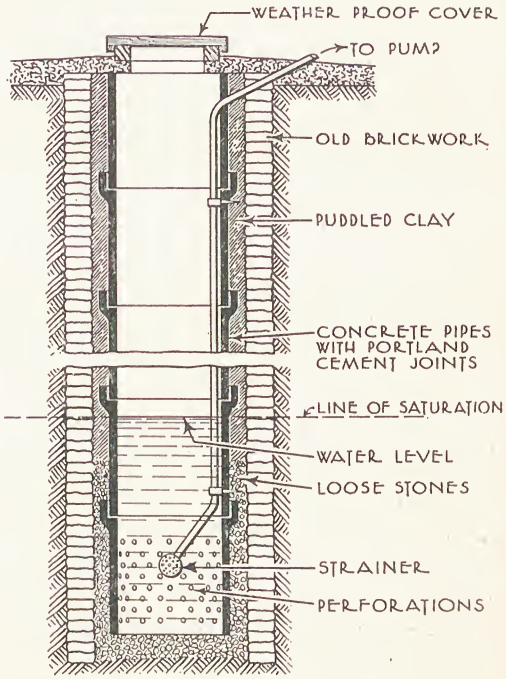


Fig. 2.—METHOD OF REPAIRING WELL

The local authority requires the analyst's report as to the suitability of the water for drinking purposes before it can be used. The surveyor need, therefore, only concern himself as to the storage.

Dual Supplies

Where there are two sources of water supply, such as is found in country districts, one being for drinking water obtained from public mains or from some other pure source, and the other being water used for washing purposes, it is most important that there be no connection between them. Taps should be labelled to prevent mistakes being made.

Overflows from rainwater tanks should be carried to the open. Where this is not possible, the overflow should be carried into some gully from which a back flow is impossible. Where the ground is porous, the overflow can be sometimes carried into a properly constructed soak away.

HEATING AND VENTILATION

PART VI.—VENTILATION SYSTEMS—DUST AND FUME EXHAUSTING—DRYING-PLANTS

RECOGNITION of the fact that breathing is essential to human and animal life should be sufficient to indicate, also, that the purity of the air we breathe is of the greatest importance in maintaining healthy conditions. The average quantity of air inhaled by a healthy man is about 30 cu. in., and if this amount is taken in by the respiratory organs sixteen times per minute, it follows that approximately $16\frac{1}{2}$ cu. ft. of air are required per hour.

In addition to the air we breathe, a movement of air over the surface of the body is also necessary to remove the surplus heat, water vapour, carbon dioxide, and organic vapours given off by the body.

Need for Ventilation

The heat from an adult varies between 220 B.Th.U. per hour, when sleeping, and 550 B.Th.U. per hour when hard at work.

As much as $\frac{1}{2}$ lb. of water vapour may be emitted hourly from a man engaged upon a strenuous task, and the emission of carbon dioxide under similar conditions may be $1\frac{1}{4}$ cu. ft. per hour.

It is evident, therefore, that apart from a supply of fresh air, it is necessary, especially in confined spaces, that there should be an appreciable movement.

In systems where good ventilation is to be maintained it is usual to allow an air change of not less than 1,000 cu. ft. per person per hour. This allowance, if made for a hall or cinema capable of seating an audience of, say, 1,500 persons, will necessitate the installation of a ventilating system capable of supplying and removing $1{,}000 \times 1{,}500 = 1{,}500{,}000$ cu. ft. per hour.

The design of a system for handling such a large volume of air requires the careful and expert attention of the engineer, who must plan the air inlets and outlets so that the air is delivered and removed uniformly to and from all parts of the room. Some typical examples of ventilation systems are illustrated on pages 275, 282, and 283. Much information may be learnt from these.

Special attention is required in the dispositioning of the inlet grilles, to avoid the possibility of complaints from draughts.

Natural Ventilation

This is the most common form of ventilation, and is obtained by the movement set up by changes in temperature. In the open, there is a continual movement caused by masses of heated air rising because of their lowered density, and being replaced by air of greater density and therefore cooler. If the windows and doors of our buildings are open, this movement extends into them. The present tendency in the design of schools and hospitals is to arrange each classroom or ward with external walls on opposite sides. The provision of windows of ample area on the two sides of the rooms permits a flow of air through them, giving what is termed cross-ventilation.

Artificial Ventilation

Artificial ventilation is obtained by the inclusion, in the construction or equipment of a building, of some device to induce a rate of air change either by the natural law of gravity or by mechanical means.

The open fireplace is a most effective non-mechanical ventilator, especially when there is a bright fire burning in the grate. The fire itself needs approximately 20 cu. ft. of air per pound of coal burnt, and the hot gases passing up the chimney carry with them a large volume of air which passes over the fire into the chimney.

Mechanical Ventilation

In our larger buildings, especially cinemas, theatres, and office buildings, where controlled ventilation is desirable, fans of either the propeller or centrifugal type should be provided.

In office buildings, where the layout lends itself to the arrangement, a convenient method of forming the air ducts is to construct false ceilings in the corridors, and to connect the ducts so formed to a vertical shaft leading to the fan chamber.

Each room is fitted with a ventilating register connecting to the air duct ; the register can be easily opened or closed. By the provision of controllable air inlets behind the radiators, the incoming air is warmed.

Fans

The resistance set up by the air passages is often sufficient to require the employment of a centrifugal fan, rather than one of the propeller type, because of its greater capacity to overcome comparatively high resistances. The frictional resistance may be approximated by using the formula :—

$$WG = \frac{1{\cdot}73L \,.\, V^2}{K \,.\, D}$$

Where WG = water gauge (in.)
L = length in feet
D = diameter in inches
V = velocity in feet per second
K = coefficient of resistance of friction.
(For brickwork, K = 12,500. For well-finished galvanised trunking, K = 25,000.)

For rectangular ducts :—

$$D = \frac{4 \times A \times B}{2(A + B)}$$

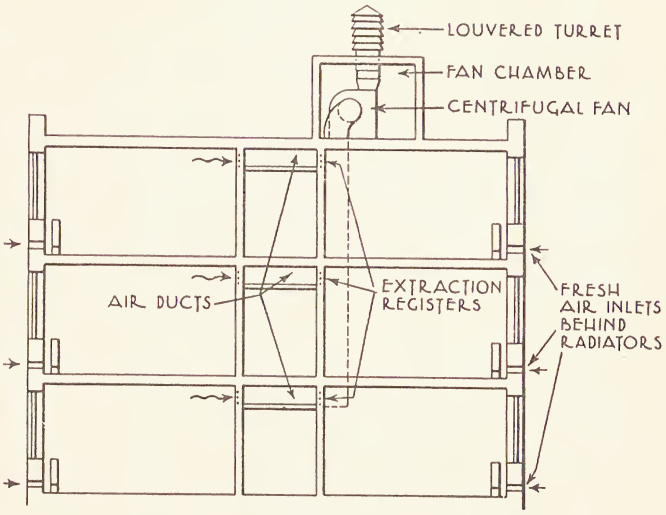


Fig. 1.—MECHANICAL VENTILATION OF OFFICE BUILDING

A convenient method of forming the air ducts is to construct false ceilings in the corridors and to connect the ducts so formed to a vertical shaft leading to the fan chamber.

Where A and B = the width and height of the rectangular duct.
D = the diameter of circular duct offering the same resistance.

In cinemas and large halls, the extraction fans are frequently fixed in the roof space, and if this is made airtight, except for the extraction grilles in the ceiling, the engineer may dispense with the use of trunking. Propeller fans are suitable for such conditions, as there is little resistance to the flow of air.

Ventilation from under the balconies must not be overlooked ; vertical ducts leading to the roof space may be provided, or independent fans.

Where propeller fans are provided, they are best fixed with vertical spindles, and discharging into louvred turrets. When a fan is arranged to discharge the air in a horizontal direction, say, through an opening in a wall, it is advisable to guard against the effects of adverse winds, which may exert sufficient pressure to overcome the power of the fan. A light, butterfly damper, arranged to swing open by the pressure of air from the fan, will prevent the extract opening from becoming an intake under the conditions described above.

Positions and Sizes of Extract Openings

The first consideration in determining the positions and sizes of the extract openings in the rooms to be ventilated, is to avoid the possibility of draughts which may cause discomfort to the occupants. The best

positions cannot be decided upon without carefully studying the plans of the building ; and in calculating the sizes of the extracts, the air velocity must be kept reasonably low, usually from 200 to 500 ft. per minute.

Noiseless operation is particularly important in schemes for lecture and concert halls and cinemas. The velocity of the air in the main ducts should, therefore, not exceed 1,000 ft. per minute, and the fans should be of the slow-speed pattern, fitted with what are termed "super-silent" motors, and fixed with anti-vibration material inserted between them and their supports, to lessen the transmission of noise. For large installations, it is advisable to consult specialists in noise-insulation.

The Main Outlet

The fan outlets should be connected to a louvred turret fixed clear of the roof top and having a free area on any two sides, calculated to pass the required volume of air at a velocity of, say, 500 ft. per minute. The angle of the louvre blades should not be less than 45°, and preferably nearer 60°, from the horizontal. A screen of wire netting or similar material should be provided at the openings, with the mesh sufficiently small to prevent birds or debris carried by the wind from entering the turret.

Access to the fan chamber must be provided for the attendant to make periodical inspections, and to enable him to lubricate bearings.

Sheet-metal Trunking

Galvanised sheet-metal trunking is largely used in the air-collecting systems of ventilating installations, and this should be of the weights already given at the beginning of this section (page 5). Care is necessary in the construction of bends and branches to prevent whistling noises being set up, which, once the plant has been put in operation, may be difficult to locate and remove.

As with fans, the manner of supporting the trunking must receive particular attention if the avoidance of transmission of noise from vibration is of importance. Felt is a useful material to break a metal-to-metal contact, and is inserted between the supports and ductwork for this purpose.

As already stated, the velocity of the air through the main ducting should not exceed 1,000 ft. per minute if silent operation is desired, but this may be increased to, say, 1,200 ft. per minute or more if silence is not so important.

The frictional resistance, velocity, and volume of air delivered by circular sheet-metal trunking is given in the logarithmic chart in Fig 2. The resistance is given in inches water gauge per 100-ft. run of straight lengths, and it is, therefore, an easy matter to estimate the total frictional resistance through any given length of trunking delivering

a known quantity of air. The resistances set up by bends may be determined by considering these in equivalent lengths of straight pipe.

Where the radius of the throat equals 2D, multiply the diameter of the trunking by 5·5.

Where the radius of the throat equals D, multiply by 6·5.

Where the radius of the throat equals ½D, multiply by 12·5.

For sharp right-angled bends, the resistance may be equal to an equivalent straight length of 75 times the diameter (D).

Velocity Head

The velocity head should also be considered in arriving at the total resistance against which the fan must work, although for ordinary ventilating schemes the velocities are usually too low to create any appreciable head. Conditions may occur, however, where it is necessary to make allowance for this pressure, which is additional to the frictional resistance of the trunking. As will be seen from the accompanying Table, dry air at 60° F., when flowing at a speed of 1,250 ft./min., creates a pressure of 0·1 in. w.g.

PRESSURE OF DRY AIR AT 60° F. AT VARIOUS VELOCITIES

Water Gauge	*Velocity ft./min.*	*Water Gauge*	*Velocity ft./min.*	*Water Gauge*	*Velocity ft./min.*	*Water Gauge*	*Velocity ft./min.*
·1 in.	1250	·6 in.	3070	1·1 in.	4170	1·6 in.	5020
·2 in.	1760	·7 in.	3320	1·2 in.	4350	1·7 in.	5170
·3 in.	2170	·8 in.	3550	1·3 in.	4590	1·8 in.	5330
·4 in.	2520	·9 in.	3770	1·4 in.	4700	1·9 in.	5470
·5 in.	2800	1·0 in.	3950	1·5 in.	4860	2·0 in.	5620

Testing

In testing air velocities, readings may be taken by the use of an anemometer, which is an instrument consisting of delicately balanced vanes fixed radially to a freely running spindle, which in turning actuates a recording pointer. The pointer moves over a dial indicating feet of air, and by carefully timing the readings, the observer is able readily to determine the velocity. Several readings should be taken at different points of the air stream, and the average calculated to arrive at the mean velocity.

Automatic Ventilation

By the provision of suitably designed outlets, the removal of air from a room can be effected without recourse to fans, and, as already explained, the open fireplace is a typical example.

The density of air at 0° F. is 0·086331 lb. per cubic foot, and this decreases as the temperature is raised, as will be seen from the Table below.

DENSITY OF AIR AT VARIOUS TEMPERATURES

Temperature, ° F.	*Density lb./ft.³ at Atmospheric Pressure*	*Temperature, ° F.*	*Density lb./ft.³ at Atmospheric Pressure*
0	0·086331	210	0·059313
32	0·080728	212	0·059135
40	0·079439	220	0·058442
50	0·077884	240	0·056774
62	0·076097	260	0·055200
70	0·074950	280	0·053710
80	0·073565	300	0·052297
90	0·072230	320	0·050959
100	0·070942	340	0·049686
120	0·068500	360	0·048476
140	0·066221	380	0·047323
160	0·064088	400	0·046223
180	0·062090	425	0·044920
200	0·060210	450	0·043686

If the temperature of the air in a room is maintained at a higher level than that of the outside air, there is, because of the difference in temperatures, a pressure difference which causes an upward movement of the heated air. By fixing a specially designed ventilator at the top of an outlet, the natural velocity of the upward current may be accelerated by the ejector action which the particular ventilator has been designed to give. Many patterns of ventilators are marketed, most of which are designed to give the same results, viz. to prevent the outlet, under adverse conditions, acting as an inlet, and to assist in the removal of the vitiated air.

A ventilating flue formed between two chimneys in a single stack is so positioned that the heat conducted through the brickwork of the chimneys is imparted to the air and so accelerates its velocity.

Other methods frequently adopted, before the use of electricity became general, were to form steam-pipe coils, or to provide lighted gas jets, in the air uptakes: both had the object of heating the air and thereby increasing the rate of ventilation.

DUST AND FUME EXHAUSTING

It is generally conceded that the old-fashioned method of removing dust by sweeping is, to say the least of it, inefficient. The popularity of the household vacuum cleaner is not solely due to the intensive selling organisations created by some manufacturers, but to the recognition on the part of the public of the need for an apparatus that would *collect* this "matter in the wrong place," as dust has been aptly described.

Effective dust-removing systems are desirable on the grounds both of cleanliness and of hygiene, not only in public gathering places, but particularly in factories, where dust from the materials may be harmful to the health of the workers. Asbestos dust, for instance, is, if inhaled, highly injurious, causing a disease of the lungs known as asbestosis. This disease is of an insidious nature, rendering the provision of adequate safeguards essential.

Central Suction Plants in Large Buildings

Portable types of vacuum cleaners are often replaced in some of the larger buildings by centralised suction plants. These usually comprise, in each case, a motor-driven fan of high exhausting capacity, to which is connected a system of tubes which extend to all floors and departments. The tubes terminate in convenient positions, usually at the skirting levels, where hinged caps, fitted to the tube ends, keep them closed when not in use. Flexible lengths of tube, fitted with suitable nozzles, are attached when cleaning operations are commenced, and the dust from the furniture, carpets, etc., is carried by the powerful suction action of the fan, through the system of tubes to the dust container.

Dust Extraction in Industry

Mechanical dust extraction in industry is applied in all branches where the increased amount of dust, resulting from the greater output made possible by the introduction of machinery, has made necessary its rapid and effective removal.

The extraction system includes a fan, separator, and collector, and the dust-conveying trunking.

The fan is of the centrifugal type, specially designed to create high velocities in the ductwork, and to overcome the corresponding high resistances. As the fan wheel must revolve at a high speed, a belt drive is usually employed, the drive being arranged from an independent motor or, if convenient, from the line shafting in the factory.

Separating Dust from the Air

In the design of the separator, the velocity of the air is allowed to drop to a speed at which it cannot hold the solid particles of material in suspension. The air then passes out at the top, and the collected refuse falls through an outlet at the bottom into a container.

Conveyor Piping

The conveyor pipes are usually constructed of galvanised sheet metal, and care is necessary to ensure that the inner surfaces are free from obstructions. All bends and junctions should be of a large radius, and where joints are made in the pipe line, the lapping end should always be arranged to face the air stream.

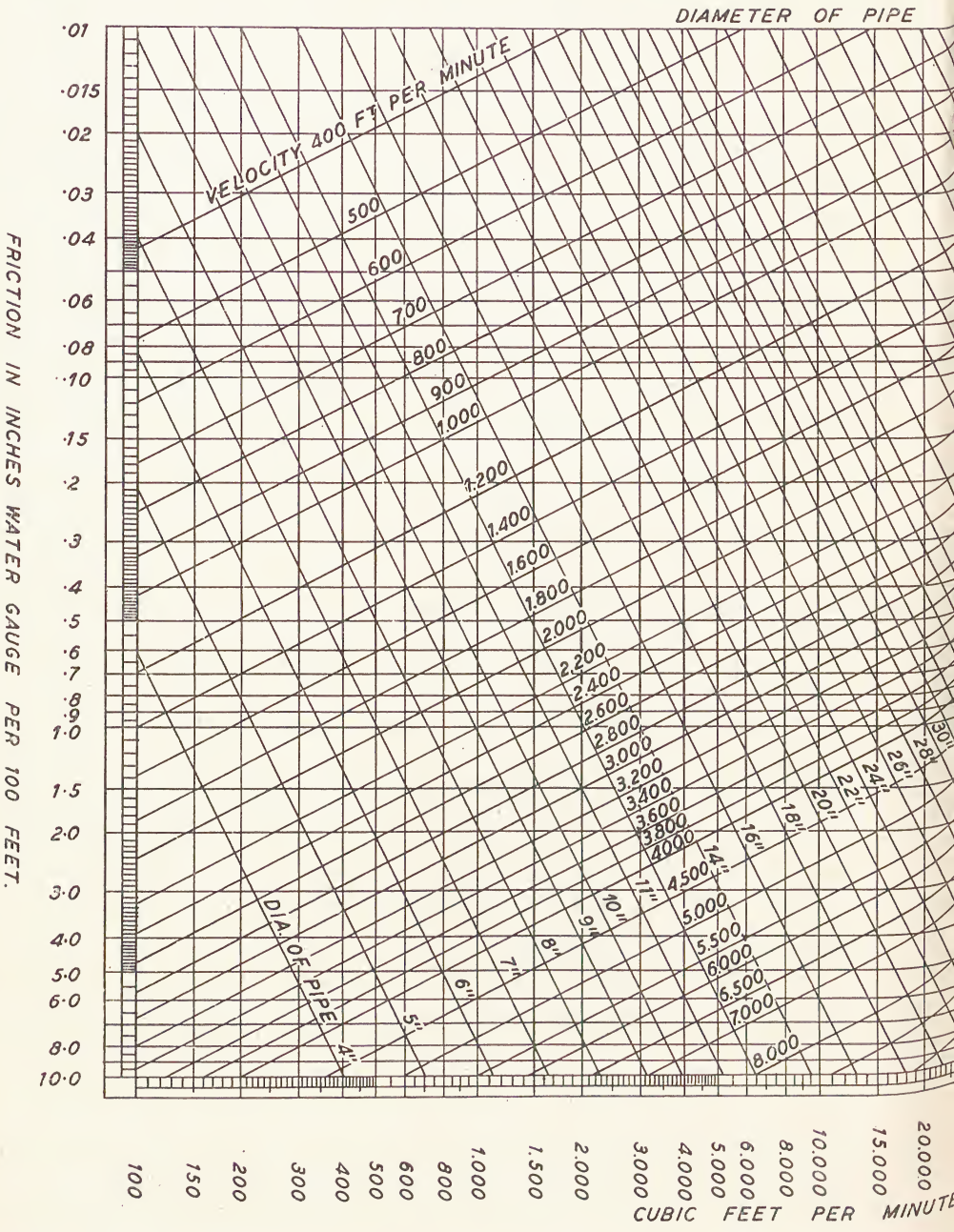
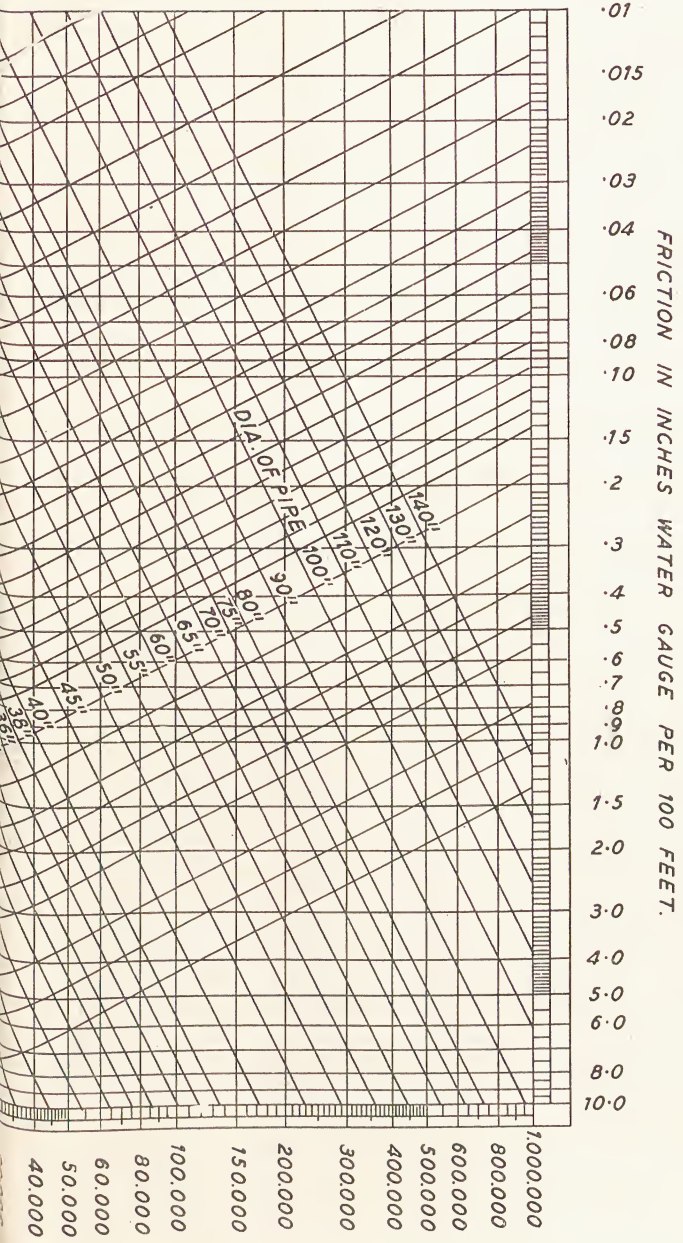


Fig. 2.—CAPACITIES AND RESISTANCE OF GALVA



D AIR DUCTWORK

Swivel-pattern dampers should not be used, but those of the sliding, cut-off type, which should be as air-tight as possible, and designed to cause no restriction in the area of the duct when fully open.

Air Velocities Required and Sizes of Pipes

The air velocities required depend largely upon the specific gravities of the materials handled, and upon the percentage of solid matter to the air volume. Only by experiment can the most satisfactory speeds be determined, but the following list indicates the average speeds found necessary in practice for various materials :—

	Ft. per min.
Fine coal	4,400
Fine brass turnings	4,200
Grain	3,200
Wood chippings and shavings	3,000
Rubber dust	2,000
Fibrous jute dust	1,900
Metal dust	1,800
Wood dust	1,300

The sizes of the pipes are governed by the quantity of material to be removed and the volume of air necessary per pound of material. For the removal of the refuse from woodworking machines, the sizes

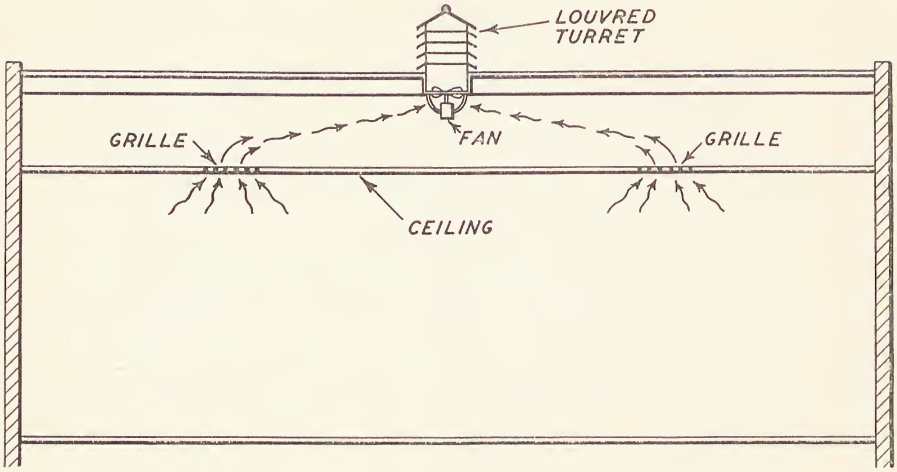


Fig. 2A.—VENTILATING PROPELLER FAN IN SEALED ROOF SPACE

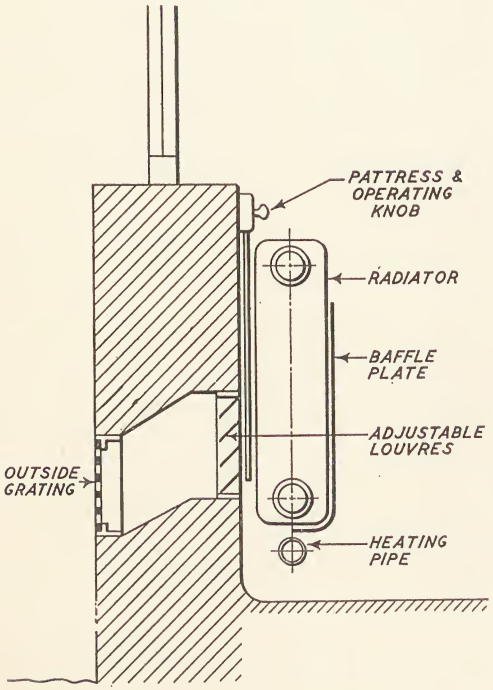


Fig. 2B.—CROSS-SECTION THROUGH FRESH-AIR INLET BEHIND RADIATOR

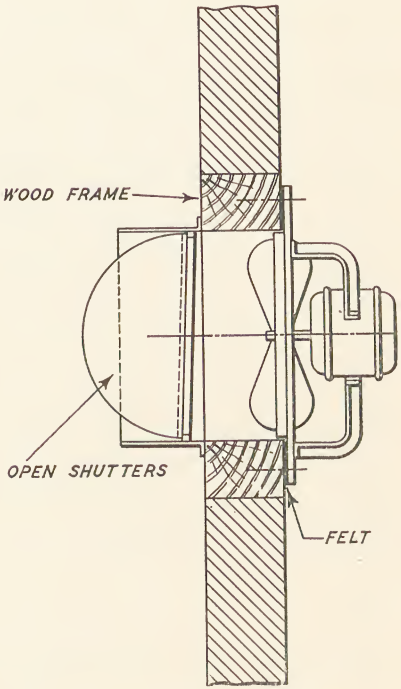


Fig. 2C.—ARRANGEMENT OF PROPELLER FAN FIXED ON WALL, WITH AUTOMATIC SHUTTERS ON DISCHARGE SIDE

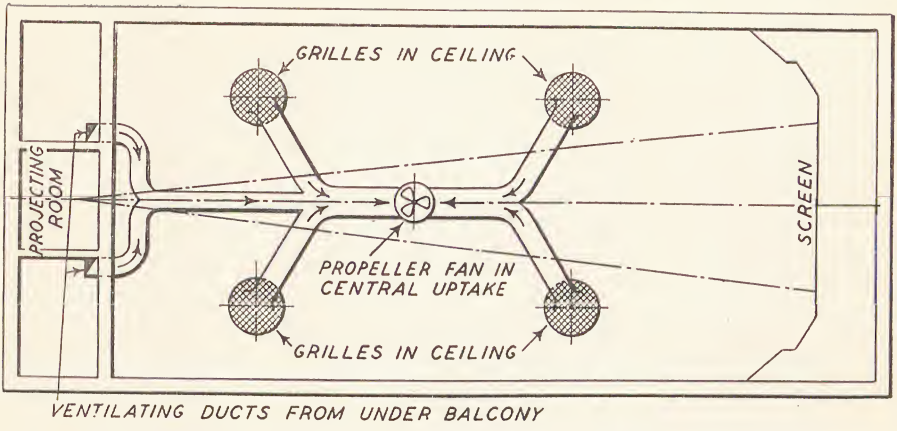


Fig. 2D.—PLAN OF TYPICAL ARRANGEMENT OF CINEMA VENTILATION

NOTE.—Grilles positioned outside width of light-beam to avoid reflection of ascending tobacco smoke.

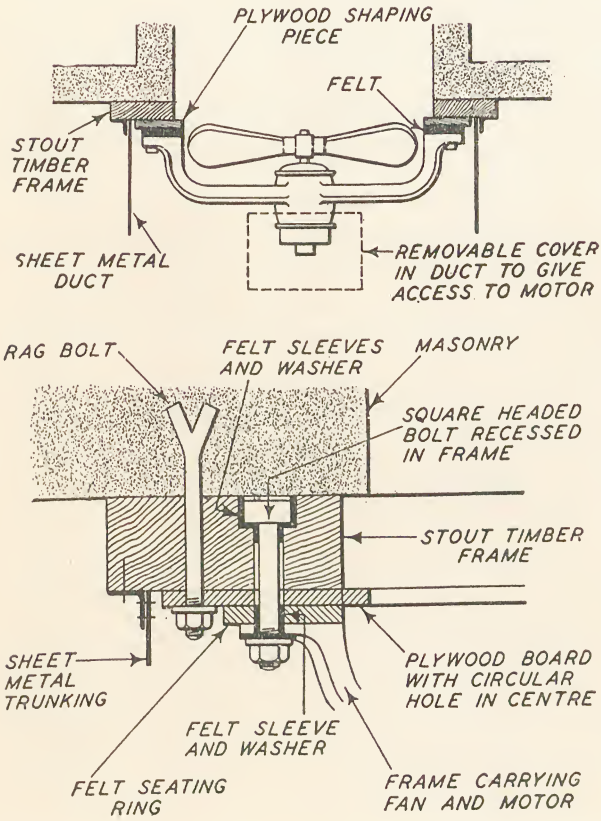


Fig. 2E (*left*).—FIXING EXTRACT PROPELLER FANS

On the left we see a suitable method of fixing extract propeller fans on ceilings where it is essential to avoid noise and vibration of the fan and motor being transmitted to the building. The metal frame carrying the fan is fixed on a stout timber frame, the motor being isolated from the timber frame by means of a felt seating ring.

From the enlarged view of the frame it will be seen that the fixing bolts are fitted with felt sleeves and have square heads recessed into the back of the timber frame, in order to avoid direct contact with the building. The frame is secured to the masonry by a separate set of bolts, so that there is no metallic continuity from the metal frame to the building structure.

If trunking is employed from the gratings in the ceiling to the extract fan, it should be connected direct either to the masonry or to the timber frame.

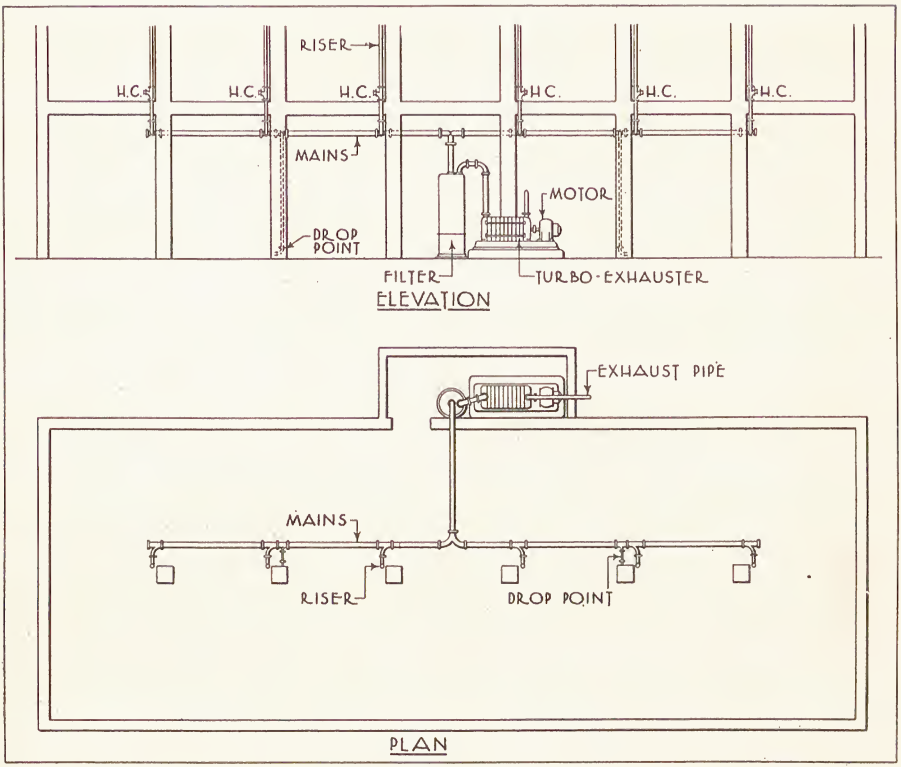


Fig. 3.—THE ARRANGEMENT OF A CENTRAL VACUUM CLEANING PLANT

The exhauster and motor are placed in as central a position as possible, to ensure well-balanced distribution of suction. The suction pipes are distributed on the basement ceiling and give off rising mains in suitable positions. Each riser has a gun-metal hose-connection fitting just above each floor.

required may be : 4-in. diameter for 18-in. circular saws ; 6-in. diameter for 24-in. to 42-in. circular saws ; 7-in. diameter for planing machines ; and for sanding machines, 8-in. diameter.

Extraction Hoods

The design of the hoods which form the inlets to the conveyor pipes needs careful consideration, as they must not interfere with the working of the machine, nor prove an inconvenience to the operator.

The static suctions required at the hoods depend upon many factors, such as the kind and quantity of the material to be removed, and the relative sizes of the hoods and their connections. For comparatively light materials, 1 in. to 2 in. water gauge may be sufficient, whereas 3 in. to 5 in. w.g. may be necessary for the conveyance of bulky and heavy substances.

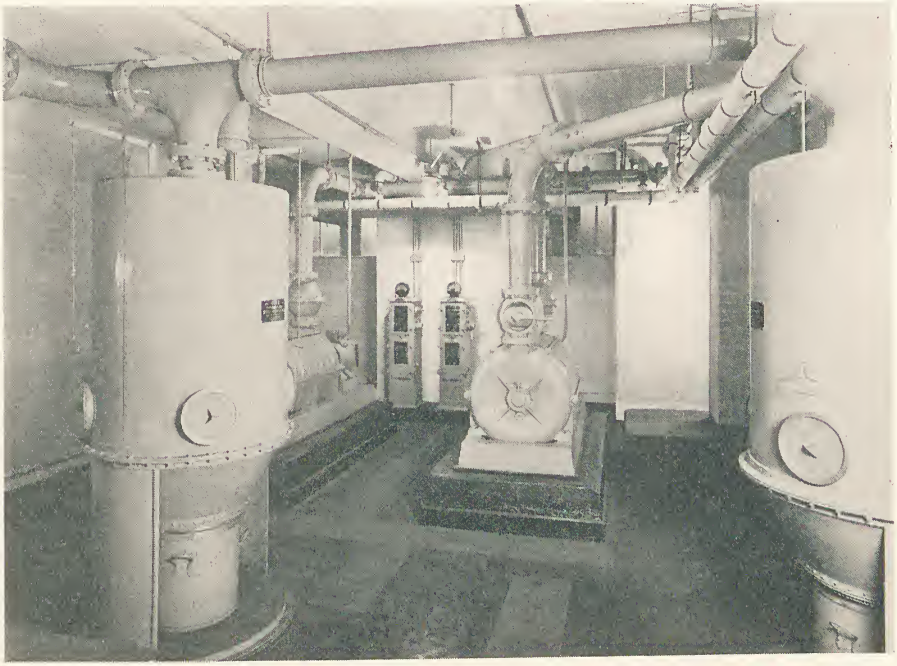


Fig. 4.—VACUUM CLEANING PLANT

This shows a 2-set installation in the London County Hall, giving a capacity of 24 operators distributed over the building, the pipe line serving 104 hose-connection points. (*The British Vacuum Cleaning & Engineering Co. Ltd.*)

Fume Removal

Fume-removal equipment is necessary wherever fumes may be produced in sufficient volume to become either obnoxious, or dangerous to health. In chemistry laboratories, the provision of fume cupboards enables experiments in chemicals giving off dangerous gases to be made in safety, and without inconvenience to the experimenter. A fume cupboard is fitted with a vertical flue discharging above the roof; when necessary a propeller fan is provided to improve the draught.

Kitchens

In the kitchens of hospitals, large hotels, and restaurants, large canopies or hoods are fixed over the boiling pans for the collection and removal of vapour. The outlets from the canopies are connected to convenient chimney flues, or so arranged as to discharge outside the building. Here again, propeller fans may be required to assist in the removal of the vapour. The cooling effect of the hoods necessitates the provision of small gutters, which are fixed inside at the bottom and piped to drain.

Chemical Fumes

The effective removal of chemical fumes produced in industrial processes must receive individual consideration. Some have a corrosive action on metals, and special treatment is therefore necessary for the protection of the ductwork and fans.

Where the fumes or gases are of such a character that rapid diffusion occurs, and there is difficulty in removing them by the provision of ventilating hoods and ductwork, increase in the rate of ventilation of the workshop is sometimes essential to maintain the air at a healthy degree of purity. As many as thirty changes of air per hour may be necessary in some cases, which require carefully designed air-heating systems for the incoming air, and the installation of large exhausting fans.

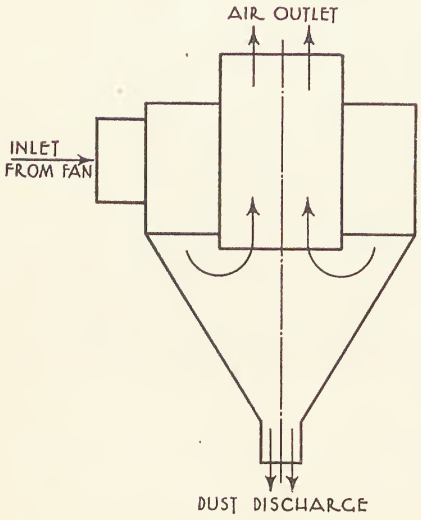


Fig. 5.—SECTIONAL ARRANGEMENT OF DUST SEPARATOR

DRYING-PLANTS

The removal of moisture from materials is usually effected by artificially increasing the movement of the air over the materials by the use of fans. By applying heat also, more rapid vaporisation of the moisture is obtained, thereby increasing the rate of drying. It is important, however, to use restraint in applying heat to certain materials, as damage is easily caused by excessive temperatures and too-rapid drying.

Drying Materials

For the drying of any material, the total heat required is equal to the sum of the following quantities :—

(1) Heat required for the evaporation of the moisture—approximately 1,000 B.Th.U./lb.

(2) Total heat losses of the drying-chamber.

(3) Heat required to raise the temperature of the incoming material to the outgoing temperature.

(4) Heat required to raise the temperature of the ventilating air to the temperature at the point of extraction.

In arriving at the first quantity, it is necessary to learn the moisture content of the material, and this is found by weighing samples before and after drying.

The weight of the material in the dry state should be taken in calculating the third item, and the specific heat of the particular substance must also be known.

The quantity of air required to carry away the evaporated moisture is found by dividing the quantity of water evaporated, by the amount of water absorbed by the air in passing through the chamber.

For example, assume that in drying a quantity of material, 30,000 grains of moisture have to be removed per hour, and that the entering air has been raised to a temperature of 100° F. and has a moisture content of 6 grains per cubic foot. Reference to the hygrometric tables published by Dr. Glaisher will show that this can be increased to 15 grains per cubic foot at 75 per cent. of the total carrying capacity of air at 100° F. It follows, therefore, that the quantity of air required is equal to $\frac{30{,}000}{(15 - 6)}$ = 3,333 cu. ft. per hour.

The temperatures not to be exceeded, in the process of drying various materials, are given below :—

Leather	68°–78° F.
Dough wares (large macaroni, etc.)	68°–78° F.
„ „ (small macaroni, etc.)	104° F.
Horsehair and substitutes	86° F.
Starch at the beginning	68°–86° F.
„ „ „ end	140°–158° F.
Glue	68°–86° F.
Wood	212° F.

In Laundries

In laundry practice, continuous drying machines are used for the rapid drying of the linen in its transit from the washing department to the ironing and finishing departments. An endless-chain conveyer, fitted with clips, carries the articles to be dried from one end to the other of a heated chamber. Powerful propeller-type fans are used to blow the air over the heating battery into the drying chamber, and to distribute and exhaust the air as it becomes saturated. The heater is usually of gilled pipes, grouped into a battery and supplied with steam at approximately 30 lb. per square inch.

QUESTIONS AND ANSWERS

How is Natural Ventilation utilised for Ventilation of School Classrooms and Hospital Wards ?

Each classroom or ward is arranged so that it has external walls on opposite sides. The provision of windows of ample area on the two sides of the rooms permits a flow of air through them, giving what is termed cross-ventilation.

What is the desirable Limit of Air Velocity at Extract Openings ?

Usually from 200 to 500 ft. per minute.

How is Noiseless Operation of Mechanical Ventilation achieved ?

(1) By limiting the velocity of the air in the main ducts to 1,000 ft. per minute.

(2) Using fans of slow-speed pattern, fitted with what are termed " super-silent " motors.

(3) Fixing anti-vibration material between the fans and their supports.

What are the essentials of a Louvred Turret for discharging air to the outside atmosphere from the fan outlet ?

(1) The turret should be fixed clear of the roof top, and have a free area on any two sides.

(2) It should be able to pass the required volume of air at the required velocity.

(3) The angle of the louvre blades should not be less than 45°, and preferably nearer 60° from the horizontal.

(4) It should be provided with a screen of wire netting or similar material at the openings, with the mesh sufficiently small to prevent birds or debris carried by the wind from entering the turret.

(5) Access to the fan chamber should be provided for the attendant to make periodical inspections, and to enable him to lubricate bearings.

How is it possible to guard against Adverse Winds causing an Extract Opening in a wall to become an Intake ?

A light butterfly damper arranged to swing open by the pressure of air from the fan will avoid this.

ELECTRICAL WARMING APPLIANCES AND INSTALLATIONS

PART I.—DIRECT HEATING

THE only term, in addition to those given in the sections on "Heating and Ventilation," with which it is necessary to be familiar in connection with electric heating, is the term "load." The term is used to denote in electrical measure the quantity of heat available for a room or building, and is, for this purpose, equivalent to a boiler rating in B.Th.U. The load is measured in kilowatts, or 1,000 watts, and is the product of amperes and volts.

The standard method of calculating the quantity of heat required by rooms has been explained in detail on pages 12 to 16 of this Volume; the same method is used for estimating the electrical load required. Each coefficient given can be converted to electrical measure and load calculated direct, but the more usual procedure is to work in B.Th.U. and then convert to kilowatts by dividing by 3,410, this being the heat equivalent of 1 kilowatt hour, or a load of 1 kilowatt in use for 1 hour.

This method of calculating load applies primarily to buildings which are warmed continuously: the loss so calculated takes place when a steady internal temperature has been reached. It is to be remembered, however, that when dealing with electric heating systems the ease with which an installation may be switched on and off almost invariably leads to intermittent use—heating by day only. With a normal load, as calculated for steady-state losses, long pre-warming periods are likely on cold days. If this annoyance is to be avoided and reasonably short pre-heating periods obtained, the load calculated for steady-state losses must be increased by about 25 per cent.

LUMINOUS RADIATORS

The use of electric fires, while very extensive, cannot be described as central heating any more than the ordinary open coal fire, and is not therefore subject to the same method of load calculation.

Under this heading comes a wide range of electric fires of every conceivable design, from the portable types to the fixed-tile type. We have not space to describe all types, if indeed any description is needed, as they can be seen in any electricity showrooms, but some remarks upon the two distinctive designs will perhaps be helpful.

Fig. 1.—AN ELECTRIC TUBULAR HEATER

It consists of a 2-in. metal tube within which a low-temperature " black-heat " element is carried. Note the spiral element is mounted on mica and porcelain supports. The working tube-surface temperature is slightly above that of a hot-water radiator.

Types of Radiator

The distinction between designs of electric fires is that one class is provided with a polished metal reflector, and the other with ordinary panel, fire-clay type element. The heating elements of all fires consist of a nickel-chromium spiral wound upon a threaded rod, as in most reflector fires, and fitted at the focal centre of a parabolic reflector or carried in grooves to form a panel. The purpose of the polished reflectors is to direct the heat emitted as radiation in one direction, and their use results in a concentration of heat in one intense beam. Such fires—which are most fashionable to-day, and while they may be preferred, and have definite advantages in large rooms—are not best suited for warming small rooms. The concentrated radiation renders the space in front of the fire rather too hot for continual occupation. The ordinary luminous radiator of the same loading will emit exactly the same quantity of heat as the reflector type, but the radiation is spread over a larger area with less intensity, and will therefore be more effective in thoroughly warming a room and not merely providing hot spots.

Installation of Electric Fires

When electric fires are used as the only heat source in a room, care should be taken to see that there is not an open flue immediately above the fire, for—no matter whether the fire installed is of the reflector or the panel type—there is heat emission by convection, and much of this loss

will pass directly into the flue and be lost. While some form of ventilation other than windows is very necessary in all rooms, the average chimney is more than sufficient. To obtain the best and most efficient results from an electric fire, the flue should be partly blocked, and the air entry lowered to below the level of the top of the fire.

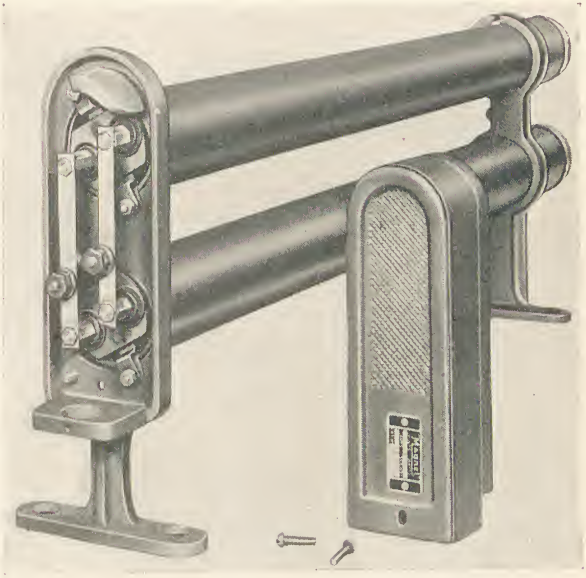


Fig. 2.—TWO-TIER TUBULAR HEATER

Showing the terminal box. Note the hole at the base of the box to allow entry of the electric cables. (*General Electric Co.*)

Slot-meter Fires

There is one type of electric fire which is of special interest to architects, as it is frequently used in hotels and boarding-houses. This fire is fitted with a shilling-in-the-slot meter, and is eminently suited to situations where rooms are not in constant occupation.

Loadings Required for Fires

The usual practice in estimating the loading required for rooms, when luminous radiators are used, is to allow from 1·00 to 1·50 watt per cubic foot of space. For bedrooms the lower value gives satisfactory results, while for a lounge or dining-room, where quick heating is required, the higher loadings are better.

Low-temperature Installations

The low-temperature installation is the electrical counterpart of the central hot-water system, and should be treated as such. For this type of installation there are on the market tubular heaters, convectors, panel heaters and thermal-storage plant. Each of these and their particular characteristics are considered below.

TUBULAR HEATERS

This type of heater, which consists of a 2-in. metal tube, or sometimes an oval tube, carrying an element internally, is to-day probably the

Fig. 3.—OFFICE FITTED WITH TUBULAR HEATERS

This shows a view of a cashier's office from the clerk's side of the counter. The tubular heaters will be seen at the foot of the counter, and the thermostats on the pillars.

most popular type of heater for direct electric heating of buildings. It is designed to fix horizontally at the base of walls by either floor or wall fixing brackets. The element consists of a low-temperature—" black heat "—spiral mounted on mica or porcelain supports, and the loading is such as to result in a tube-surface temperature of approximately 190° F. within about 10 minutes of switching on, thus the temperature is slightly above that of a freely supplied hot-water radiator.

Loadings

When used for ordinary situations the surface temperature is of course proportional to the loading per foot length, which is standardised at 60 watts per foot. The low surface temperature of tubular heaters gives rise to very low-velocity convection currents, thus there are very small temperature differences between floor and ceiling levels in a room, and an even temperature distribution throughout the heated space.

Where tubes with other than standard loadings are used, as in tubes fixed overhead, the approximate surface temperatures are as follows :—

Fig. 4.—TUBULAR HEATER INSTALLATION IN A CHURCH
The usual procedure, as shown above, is to fix the tubes under the pews.

Fig. 5.—TUBULAR HEATER INSTALLATION IN A CHURCH
The thermostat control fixed behind the pulpit.

Watts per Foot Run	*Approximate Surface Temperature for 2-in. Painted Steel Tube*
20	75° F.
40	140° F.
60	190° F.
80	260° F.
100	300° F.

Lengths Available

Tubular heaters are available in all lengths from 2 to 17 ft., or from 120 watts to 1,020 watts in single lengths. It is generally not possible to install the required load with only one row of tubes. Tubes in banks must therefore be used, and these are available in up to four tiers. When tubes are used in tiers there is a small increase in surface temperature. Tiers are made up by mounting tubes horizontally above each other with a common terminal box, so that only one electrical connection is required. The conduit entry is on the under side, thus permitting a very neat finish by bringing cables up through the floor straight into the terminal box.

Fig. 6.—A CONVECTOR

The method of operation will be clear from Fig. 7. (*Unity Heating Ltd.*)

Decoration

The relatively low surface temperature of tubular heaters permits decorative finish to be applied, in order that the tubes may harmonise with the surroundings. The only surface treatment to be avoided is metallic paint. This surface finish causes excess surface temperatures due to interference with the free emission of heat by radiation. On the same score, the standard loading should be reduced to about 40 watts per foot, if the usual surface temperature of about 190° F. is not to be exceeded with nickel- or chromium-plated tubes. While on

the subject of decorations it might be mentioned that with tubular heaters there is little or no risk of "dusting." The large, massed surface of a hot-water radiator often gives rise to black marks upon a wall. This marking is known as dusting.

Supplementary Heating

As a supplementary source of heat, tubular heaters are extremely useful in long rooms heated by open fires. A short length of tube fitted under a window or in a skylight is most effective in suppressing down draught. Further, relatively a small load in such a room will prevent a fall to a low temperature when the fire is not in use. They also prevent the room becoming damp by causing air movement due to convected currents rather than by causing temperature rise.

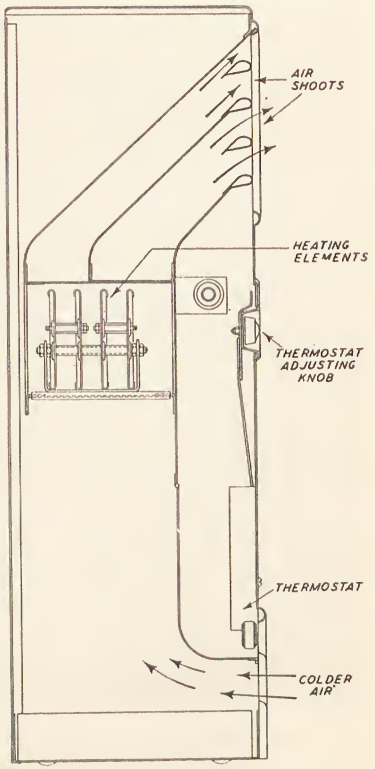


Fig. 7.—SECTION OF CONVECTOR

Colder air enters at bottom, passes over and is heated by the heater elements, and leaves through top grill.

Layout of Tubular Heaters

The layout of tubular heating systems in ordinary rooms should be made with reference to the cold or exposed sides. Some lengths should always be placed under windows. In this position the cold down draught from the windows is checked, thus removing one of the most fruitful causes of discomfort in an artificially warmed room.

Tubular Heaters in Churches

In churches the usual procedure is to fix tubes under the pews. This is generally the only way in which the necessary load can be installed, and it is a layout which permits conditions of comfort to be obtained most quickly without thoroughly warming the building. Where intermittent warming is used in churches, care is required to see that the heaters are evenly distributed, otherwise down draughts result in positions where there is a scarcity of heating surface. This applies particularly to the chancel. The large quantity of warm air rising from the heaters in the body of the church is replaced by cooler air from the upper regions, which becomes a bad draught unless checked by additional heaters. Down

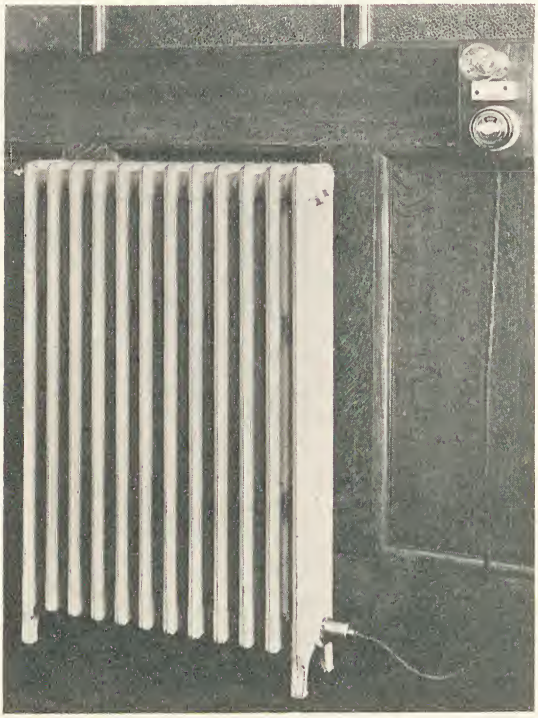


Fig. 8.—HOT-WATER RADIATOR FITTED WITH ELECTRIC IMMERSION HEATER
(*National Radiator Co. Ltd.*)

draughts from tall windows can be eliminated by fixing tubes at a level of about 20 ft. from the floor, or immediately under the window. High-level tubes are frequently loaded to 70 or 80 watts per foot. In modern churches, with their relatively low roofs, the ordinary wall positions are satisfactory, but the pre-warming period with this arrangement is slightly longer than with the pew position. The duration of the pre-warming period is of course proportional to the load, but averages about 2 to 3 hours.

Cinemas

Tubular heaters have been fitted under seats in cinemas, but for this type of installation reference must be made to local regulations, as many authorities will not permit this layout unless a very low surface temperature is used. In modern cinemas, with air requirements proportional to the seating capacity, tubular heaters are used only to offset building heat losses, the heat required by the ventilating or air-conditioning plant being supplied by a battery of heating elements fixed in the ducting close to the ventilating fan.

Schools

For schools, generally infants' schools, it is frequently necessary to provide guards, or alternatively use tubes of about 50 watts per foot, as the normal surface temperature is considered too high to be freely exposed to children.

Tubular heaters are not suited for open-air schools, panel heaters, as later described, being used.

Factories, Workshops, and Garages

The robust design of tubular heaters renders them particularly suitable for this type of building, but rarely can the floor position be used.

An alternative is to fix overhead to roof ties and use high loadings. The maximum load for a standard 2-in. tube is about 90 watts per foot-length. When heaters are fixed overhead there is a loss of effectiveness of about 20 per cent., and the installed load should be increased accordingly.

CONVECTORS

Convector is the name given to that class of appliance in which low-temperature elements are surrounded by a rectangular, plain or ornamental, metal case. Most designs are fitted with deflector plates and air-shoots to direct the hot air forward and prevent overheating of the top of the convector. The advantage of this type of heater is that it can be made to look far more attractive than tubes, and allows for relatively high loadings to be fitted in small spaces, and in situations where tubes cannot be accommodated, such as in staircase wells.

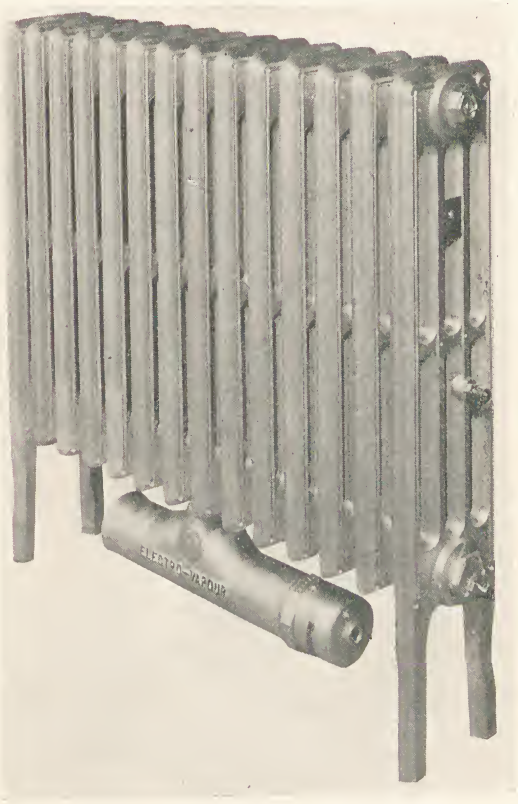


Fig. 9.—ELECTRO-VAPOUR RADIATOR

Under working conditions, the upper part becomes filled with steam. Temperature about 215° F. (*Benham & Sons Ltd.*)

Fitting Flush with Wall Surface

It will be seen from the design of this type of appliance that convectors can be sunk flush with a wall surface. When this is done, grills are provided at top and bottom, but the area of the outlet must not be reduced so as to hinder the free flow of air through the grill. There is some small temperature rise in the element when used in this position.

Some designs of convectors are fitted with adjustable thermostats. The heat-sensitive strip is at the bottom of the heater casing. In this position it is subject to the lowest air temperature in the room, which is that which has circulated around the room and is approaching the heater to be reheated and recirculated.

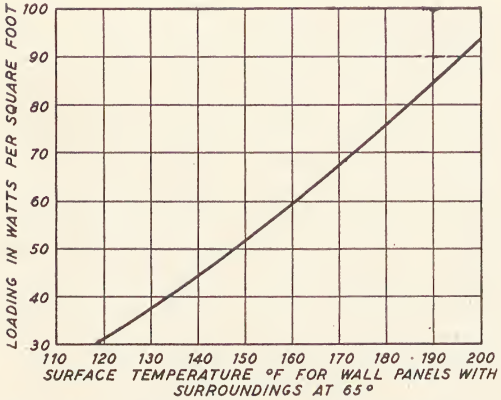


Fig. 10.—VARIATION IN SURFACE TEMPERATURE WITH LOADING OF VERTICAL WALL PANELS

Hot Water and Vapour Radiators

Although the word radiator is part of the name of this appliance it is actually a convector, and may therefore be mentioned here. There are two types—water and vapour. Both types consist of ordinary cast-iron radiator fitted with immersion heater, safety valve, and filler cap. The water-type radiator is, except for a small air space at the top, filled with water, and has a working temperature of about 180° F. The vapour type is actually a steam radiator, for it contains only a small quantity of water. Under working conditions the upper part becomes filled with steam at low pressure; working temperature is of the order of 215° F.

The Table below gives the loadings required for radiators of different sizes, and is also useful in cases where it is desired to substitute direct electric heaters of any type for existing hot-water central heating. In these cases the electrical load required can be estimated by finding the extent of the existing radiator surface and referring to the Table.

ELECTRICAL LOADINGS REQUIRED FOR HOT-WATER RADIATORS

Type of Radiator	*Height in Inches*	*Watts per Section for 160° F. with Air at 60° F.*	*Height in Inches*	*Watts per Section for 160° F. with Air at 60° F.*
"Classic" 4 column	36	140	24	94
	30	120	18	70
"Classic" 6 column	36	200	24	133
	30	170	18	100
Plain single column	38	140	26	95
	32	120	23	75
Plain double column	45	230	26	120
	38	182	20	91
	32	150		
Hospital	36	135	24	92
	30	115		

PANEL HEATERS

This type of heater gets its name from the fact that it presents to the room a flat surface and is frequently framed in moulding. Panel heaters can be used in the ceiling, floor, or wall position, but in any case must be provided with thermal insulation at the back in order to prevent loss of heat.

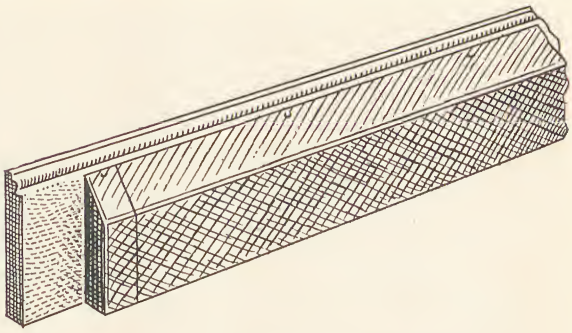


Fig. 11.—SKIRTING PANEL HEATER

This type of heater is also made in forms to take the place of the skirting board. (*John Lightfoot Ltd.*)

Surface Temperature

In the ceiling position, facing downwards, a panel may be said to emit more of its heat by radiation, for in this position the heat loss by

Fig. 12.—ARRANGEMENT OF HIGH-TEMPERATURE PANELS IN A SCHOOL

The panels will be seen hung at an angle to the walls. Temperature 400° F. The centre pendant is a radiation thermostat, specially for use with electric radiant heating. (*Unity Heating Ltd.*)

Fig. 13.—THIS ROOM IS HEATED BY THE "DULRAE" SYSTEM OF LOW-TEMPERATURE RADIANT HEATING

The ceiling has a covering of asbestos paper into which an electric heating wire is woven. (*Richard Crittall & Co. Ltd.*)

convection is largely suppressed. For a panel set in the floor or in a wall there is a larger component of heat loss by convection. Convection is highest in the floor position. From these considerations it will be seen that for panels of equal loading, which emit the same total quantity of heat, the surface temperature in the ceiling position is higher than for the wall position, while the floor-position temperature is lower than for a wall panel.

The variation in surface temperature with loading is shown in Fig. 10. This curve is for vertical wall panels with surroundings at 65° F.

Application of Panels

Panel heaters or radiators can be used in almost any room, but when fitted to ceilings in single-storey buildings extra insulation at the back is required to prevent excessive heat loss. Where the ceiling of one room corresponds to the floor of a room above, heat loss from normal panel insulation contributes to warming the room above.

Floor panels, which should not exceed a surface temperature of about 68° F., are used in churches and large rooms with high roofs. For these buildings, the panel is fitted in a position similar to the gratings which usually cover hot-water pipe trenches.

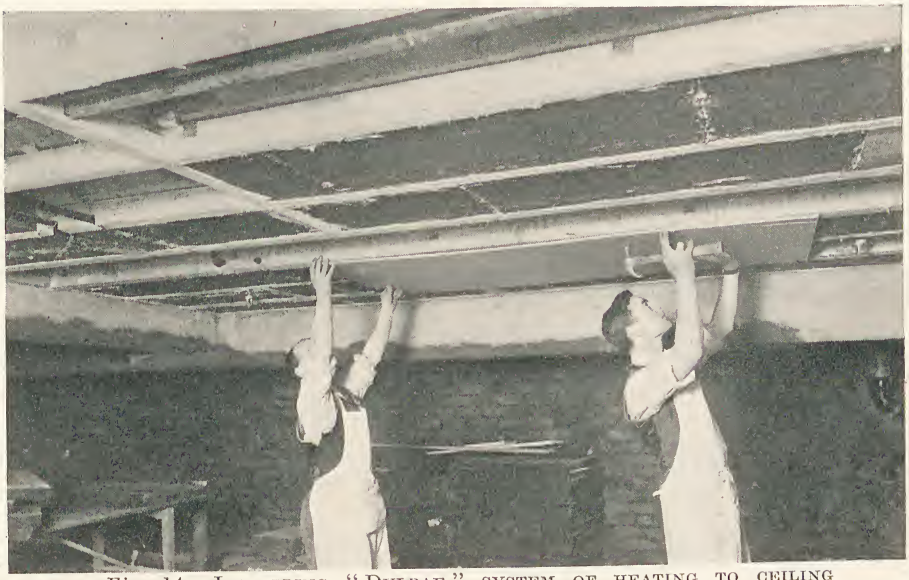


Fig. 14.—INSTALLING "DULRAE" SYSTEM OF HEATING TO CEILING

This shows the formation of an insulated base for the "Dulrae" sheets. Two-inch thick slab cork has been placed in position between wood battens. "Paramount" sheets are about to be erected.

Fig. 15.—INSTALLING "DULRAE" SYSTEM OF HEATING. THE NEXT STAGE

"Paramount" boards in position and "stopped." The "Dulrae" sheets are being hung. Note, on the left, adhesive being applied to the next "Dulrae" section for hanging.

For open-air schools, churches, or open balconies, panels have great advantages over the ordinary convector heater, in that they emit radiation direct and provide some degree of comfort irrespective of air temperature.

Skirting Panels

Skirting panels, which are made to take the place of the ordinary skirting board, are used as a subsidiary source of heating, for the relatively low temperature required for this position generally prevents installation of the necessary load for complete heating of a room.

Construction

Panel heaters are constructed of either cast iron or sheet metal, and although cast iron is a slightly better emitter of radiation than sheet metal, cast-iron panels are necessarily more heavily constructed and must therefore be properly supported. In the cast-iron type, elements are carried in ducts in the casting, while in the sheet-metal type they are clipped to the back of the panel face. The element is, of course, of nickel-chrome wire operating at a low temperature. Panels may be decorated with any type of finish except metallic paint.

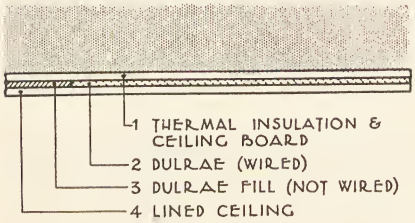


Fig. 16.—SECTION OF "DULRAE" (*Richard Crittall & Co. Ltd.*)

Determination of Load for Panel Warming Installations

The method of determining heat required for panel warming is to calculate carefully the heat loss from the room in the usual way, with due allowance for exposures, but whereas for a small room with convection warming 2 air changes per hour would be allowed for, where ceiling-type panels are to be used the calculation would be made for between ·5 and 1 air change per hour. This method allows for the increased effectiveness of direct radiation in providing comfort. The method is perhaps somewhat illogical, but experience has proved it most satisfactory, and it can be used with confidence until one of the newly proposed methods has been proven.

Warming by Radiation

Panel heating has come to be known as radiant heating, and it is claimed that by its use the same conditions of comfort can be obtained with a lower air temperature than for warming by convection. This results in a lower load per room because of a decreased temperature

difference between inside and outside air, and therefore a lower annual consumption of energy.

There is still some controversy as to the merits of warming by radiation or convection, but whatever be the final answer the fact remains that panel warming is rapidly gaining popularity, and for solidly constructed buildings offers definite economies over heating by convection.

High-temperature Panels

There is a further type of panel which is particularly useful for open-air schools or sanatoria and the like. This panel operates at a temperature of the order of 400° F., and is hung either horizontally high up in a room or at an angle to the walls. It is also incorporated in light fittings.

"Dulrae"

The panel heaters just described are constructed of metal; there is, however, a further type, which consists of asbestos paper into which an electric heating-wire is woven. This wire operates at a very low temperature, and the paper is pasted to the ceiling. A covering of ceiling board is then applied and the ceiling finished in the usual way. This type of warming equipment is marketed under the name of "Dulrae," and its installation is essentially a specialist's undertaking.

The "Dulrae" method of warming rooms approaches as near as any method to the ideal. It is well known that most discomfort in artificially warmed rooms is due to cold walls. "Dulrae" not only emits low-temperature radiation, but it contributes very largely to warming the fabric of the building itself, and gives a thoroughly warmed room without excessive air temperatures.

THERMOSTATS AND THERMOSTATIC CONTROL

Advantages of Using Thermostats

The fact that the average winter temperature in England is of the order of 42° F., and that central-warming schemes are designed to maintain an inside temperature of, say, 62° F. when the outside temperature is 32° F., indicates that unless the heaters are switched off, overheating and therefore waste of energy will result when the outside temperature rises to, say, above 32° F. This switching off is done automatically by thermostats. From the foregoing winter temperatures, it will be seen that it is possible by the use of thermostats to save some 25 per cent. of the possible energy consumption in a building. Further, a thermostat takes advantage of any incidental sources of heat in a room, such as heat emitted by occupants or by lights. Fully 95 per cent. of the energy consumed by an electric lamp is emitted as heat. Where indirect lighting is used this may be considerable. In some restaurants the heat

emitted by the lighting load is greater than the heat delivered by the heating system.

How They Work

Thermostats are switches operated by a heat-sensitive element such as a bi-metal strip which expands or contracts with rise or fall of temperature. Most designs are provided with an adjusting knob, and allow for adjustment between temperature limits of 32° F. and 75° F. Specially calibrated instruments are available for other temperatures. Most room thermostats have a differential of about 3° F., that is, if cut-off takes place at, say, 60° F., cut-in temperature will be about 57° F.

Thermostats should be fixed at about breathing-level, and shielded from direct draught or direct radiation from heaters. A request is frequently made for flush thermostats, but under such conditions the thermostat would be influenced by the wall temperature, whereas for the best results they must be exposed freely to air circulation.

Methods of Control

In small rooms, with loads of up to about 3 kw., or currents of 15 amp., it is customary to control all heaters by thermostat, so that when temperature is reached the whole of the heaters are switched off. In larger rooms and halls this is not necessary. It is sufficient to place about 80 per cent. of the load on automatic control, the balance being hand switched. This arrangement not only reduces capital cost, but eliminates considerable wear on the thermostats. At all times during the winter some heat is required by a building, and all regularly occupied buildings should be partly warmed over-night. If about 15 per cent. or 20 per cent. of full load is left connected, and the main, thermostatically controlled load switched off, then an over-night temperature of about 50° F. could be maintained, and the margin of about 25 per cent. additional allowance for pre-warming, referred to at the beginning of the chapter on electric heating appliances, could be reduced to about 10 per cent. to 15 per cent., with a consequent saving in expenditure. The main heating load can be switched on by time switch.

Heaters for Thermostatic Control

All heaters placed under thermostatic control should have low thermal capacity. All electric heaters except the hot-water type can be so controlled. With this latter type, the heat stored in the radiator is such that there will always be a temperature rise after thermostats have cut off, and the temperature of the room varies over a range of from 6° to 8° F., which is sufficient to cause discomfort.

Electric fires, of course, should not be thermostatically controlled.

MODERN DOMESTIC KITCHEN PLANNING AND EQUIPMENT

THE development of modern kitchen planning in England dates roughly from the immediate post-war period. Prior to this, the kitchen was not regarded as of great importance by house designers, and received very little serious attention. This was, to some extent, due to the prevailing outlook of the time, which regarded such a purely practical part of the home as unworthy of careful consideration.

However, the War and its aftermath brought many changes, and the rise and development of the science of kitchen planning took place, influenced by three main causes : firstly, the so-called " servant shortage," which brought to the attention of the housewife the necessity for improved and simpler methods of cooking ; secondly, the introduction—chiefly from North America, where a different domestic outlook was already established—of labour-saving household equipment and the principles of modern domestic science ; and, thirdly, the new architectural approach to the planning of the home, with its emphasis on fitness for purpose.

A great deal of research was carried out to find means of improving the kitchen, and much ingenuity has been exercised in the invention and discovery of labour-saving devices. Planning has been carefully studied, and new materials tested, and, from the experience so gained, certain principles which provide a guide to the design of the successful kitchen are now generally accepted.

Position of Kitchen

The position of the kitchen in the general plan is a point which requires consideration at the very outset. It is usual to place it on the north or east side of the dwelling, partly because it is cooler, but chiefly because the sunnier aspects are required for the living-quarters. However, as modern cooking methods do not allow the kitchen to become overheated, there seems to be no reason why the room should not be arranged to get a certain amount of fatigue-dispelling sunshine.

Wherever possible, the kitchen and the dining-room should be on the same level, and it should not be necessary to negotiate steps in serving from the one to the other. In cases where, owing to the exigencies of the site or other causes, it is necessary to plan the two rooms on different floors, they should be placed as nearly over one another as can be conveniently arranged, with simple and direct access between them. In the larger

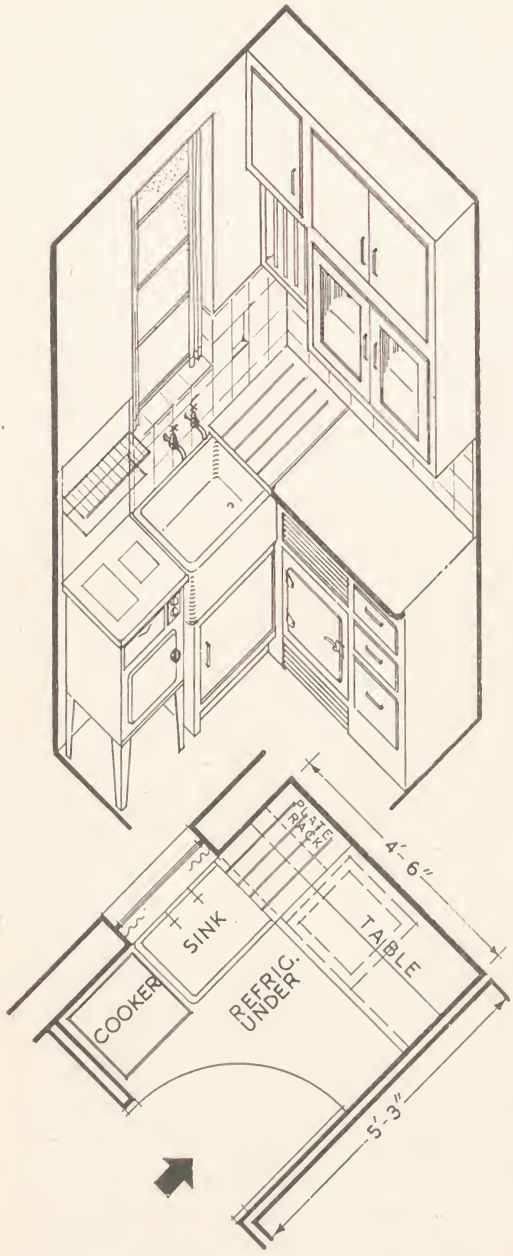


Fig. 1.—A KITCHEN OF MINIMUM DIMENSIONS FOR A FLAT

This is quite satisfactory for simple meals for one to three persons.

house, a small service lift communicating with a servery adjacent to the dining-room is desirable in such cases.

Layout of Equipment

Kitchen activities proceed along certain definite lines, and the layout of the equipment should follow the sequence of operations as closely as possible. This principle holds good for all types and sizes of kitchens. Briefly, the sequence of work is as follows : first comes the food storage section—larder and refrigerator, which should be near the trades delivery entrance ; next comes the preparation section, the main work table or kitchen cabinet ; then the cooker, adjacent to which is the dishing-up table conveniently situated for service to the dining-room by hatch or servery. The position of the sink, which is used, not only at one stage, but throughout the above sequence, is, in actual practice, best placed between the work table and the cooker, as it is used chiefly and about equally in connection with these two sections.

The placing of secondary items of equipment is partly determined by their use or function, but they must on no account confuse the main circulation.

The tendency at the present time is to avoid subdividing the domestic

quarters of the house into several small units, i.e. kitchen, scullery, separate larder and stores, etc., but to plan one large working kitchen. This makes for greater ease in running, and saves a good deal of space. Any necessary subdivision of functions is provided for in the arrangement of the equipment—fitments being used to separate certain sections.

Size and Shape

The size of the kitchen depends, of course, on the individual requirements of the family, although these are not always known, but it should not be too big, or the cook will have to take many extra steps in going about her work. Twelve feet by 10 ft. is a good size for the average family house, where one person normally does the cooking. The shape of the kitchen should be rectangular, and regular in outline. If it contains awkward angles or numerous corners it will be difficult and expensive to equip in a satisfactory manner. Where space is limited, as in flats, it can be kept to about 6 ft. in width, thus enabling equipment to be ranged on both long sides, with the minimum working space between.

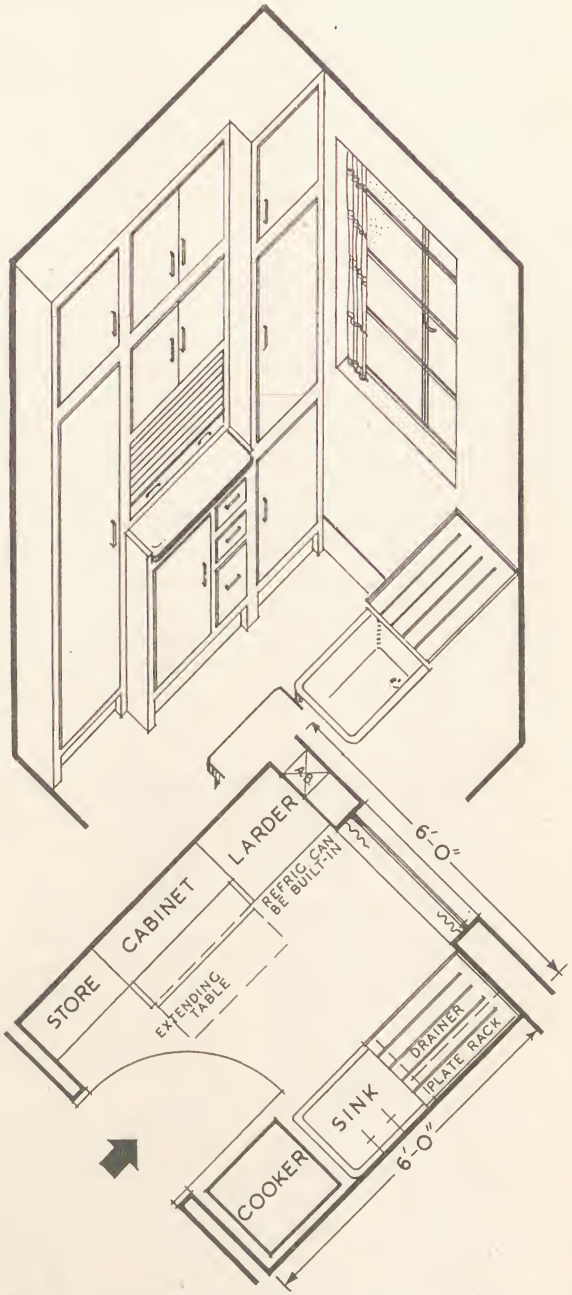


Fig. 2.—A KITCHEN OF SLIGHTLY LARGER DIMENSIONS Capable of dealing with the ordinary daily needs of two to four persons.

Equipment

The principal points to be observed about the design of any item of equipment for use in the kitchen are : (1) resistance to the deleterious effects of heat, moisture, and grease ; (2) capacity to withstand hard wear and frequent cleaning ; (3) efficiency coupled with economy ; (4) hygienic—i.e. easily cleaned, with no crevices or dust-traps.

Refrigerators

A refrigerator is almost an essential to the modern kitchen. It not only keeps food fresh and cool, thus preventing waste, but also provides ice cubes, and widens the range of sweets, etc., particularly in summer. Many types and models are now available, including a variety of sizes for building into fitments—they can often be conveniently incorporated in larder units or beneath draining-boards and counters. Very small cabinets are obtainable for use in flats, or for supplementary use as in nurseries or pantries. A 2- or 3-cu. ft. internal capacity size is generally suitable for a three- or four-bedroom house. For use in flats and similar groups of domestic buildings the installation of a central plant should be considered, with small cabinets fitted in the individual kitchens. This system is more economical than a number of smaller plants.

A well-designed and efficient refrigerator is one that is easily cleaned inside and out, has conveniently arranged shelves, is fitted with cold control and automatic operation, and is silent when running.

Cookers

The type of cooker chosen for a particular scheme will depend on the fuel available and its cost in various districts.

Gas cookers are the most economical in the average dwelling at the present time. Many different models are available, and almost all, by constant improvement in recent years, have reached a very high standard of efficiency and good design. Instantaneous ignition and automatic oven control are important refinements to watch for in choosing a model.

Electric cookers have certain advantages over other types, although current is still expensive in some parts, and they are wasteful in the hands of inexperienced maids. Their chief virtue is that there are no combustion and, consequently, no fumes.

Whether operated by gas or electricity, table-height cookers—i.e. with the oven raised level with and to one side of the boiling plate—are to be preferred, as stooping is thus avoided.

Care must be taken in the selecting of the cooker that the oven door opens correctly according to its position in plan.

Solid-fuel burners of the heavily lagged type, known as heat-storage cookers, are very economical to run, and are extremely efficient in the hands of a good cook. They are particularly suitable for large establishments, especially country houses, although it is usually desirable to have

also a small gas or electric cooker for dealing with small or occasional meals.

Sinks

The four principal types of sink in common use are teak, stainless metals, porcelain enamel on cast iron, and glazed earthenware.

The most usual type for the small kitchen is the 24-in. by 18-in. by 10-in. white-glazed Belfast sink, supported, as a rule, on cast-iron cantilever brackets. It has become almost the only standard for the ordinary house or flat in England, but, it should be remembered, there are several other sizes of the same kind of sink, one of which might be more suitable according to the individual requirements of the job. In Scotland, where home washing is more common, the double sink, with one deep and one shallow bowl, is the general standard. The fire-clay sink is comparatively cheap, but its chief drawback is that it requires a separate draining-board, with its awkward dirt- and grease-collecting junction at the rim.

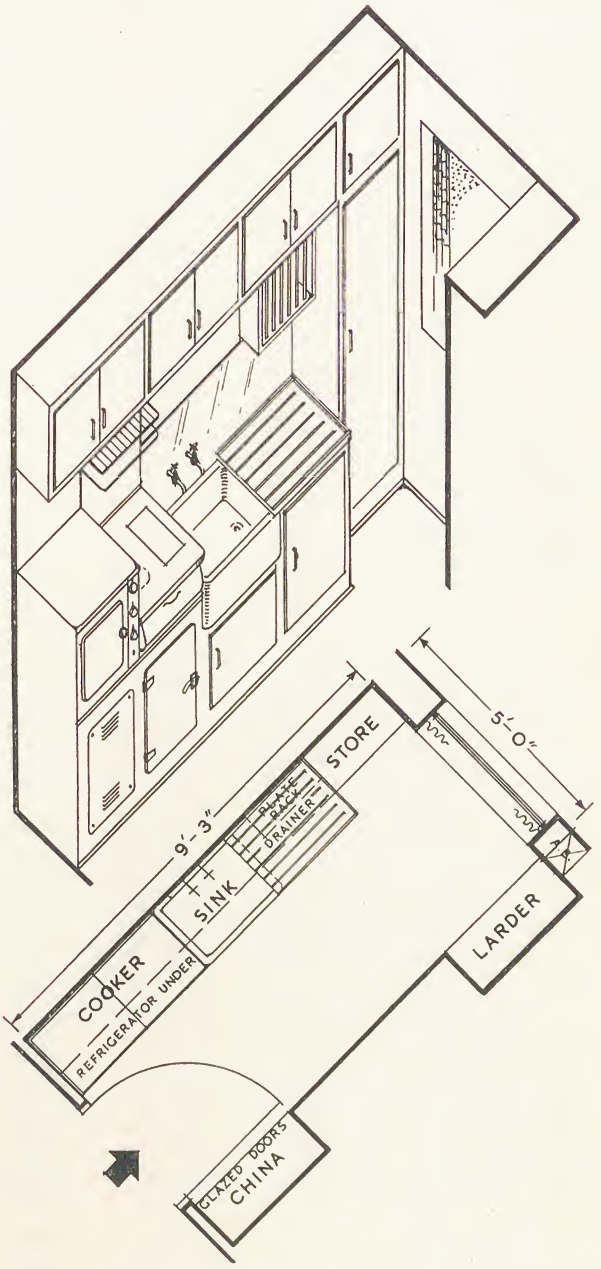


Fig. 3.—ANOTHER KITCHEN FOR A FLAT OF TWO TO FOUR PERSONS

If space permits, draining-boards should be provided at both sides of the sink, so that dishes can be stacked on one side, then washed and put on the other. When only one draining-board is possible, it is considered better on the left-hand side.

Metal sinks of stainless steel or monel metal are now marketed in a variety of sizes and types, with either single or double bowls, and one or two drainers. Of homogeneous construction, they are extremely hygienic. They are comparatively expensive, but are attractive in appearance. Breakages of crockery, which might be thought to be a drawback, are said to be lessened by the resiliency of the metal, and various methods of sound-deadening are employed to overcome excessive noise.

The porcelain-enamel-on-cast-iron type of sink is not as common in this country as in America, but, when constructed with the bowl, drainer, and splashback all in one piece, it is a very satisfactory design.

Where sink with two bowls or double sinks are used, swivel mixing taps will be required.

Kitchen Cabinets

One of the greatest developments in modern kitchen design was the introduction of the kitchen cabinet, a composite piece of equipment for the storage of everyday dry goods, kitchen cutlery, cooking implements, etc., including also a working table. It is not possible here to describe the many types of cabinet which are now manufactured, or to trace its development in recent years, but, as the forerunner of almost all the many present-day fitments, which amplify but do not supersede it, it is still, in most ordinary kitchens, the best way of providing the essential work centre. A well-designed kitchen cabinet is one in which the arrangement of cupboards and drawers is for the greatest possible convenience of the cook working at the table, the disposition of the sections for the various contents having been carefully studied in relation to their use. The construction and finish of the cabinet should be of the highest quality.

An important point to bear in mind when the cabinet is used with side units, i.e. fitments adjoining, is that the doors to the cupboard immediately over the work table should be replaced by a roller shutter. The reason for this is that the centre part of the cabinet is kept constantly open when in use, and if it has doors these will foul the doors of adjoining cupboards.

Standard Cupboard Units and Built-in Fitments

Probably nothing has so changed the appearance of the kitchen as a whole as the use of built-in fitments, composed either of pre-fabricated standardised units or of purpose-made cupboards built up on the job.

Standardised units are now manufactured by a number of firms

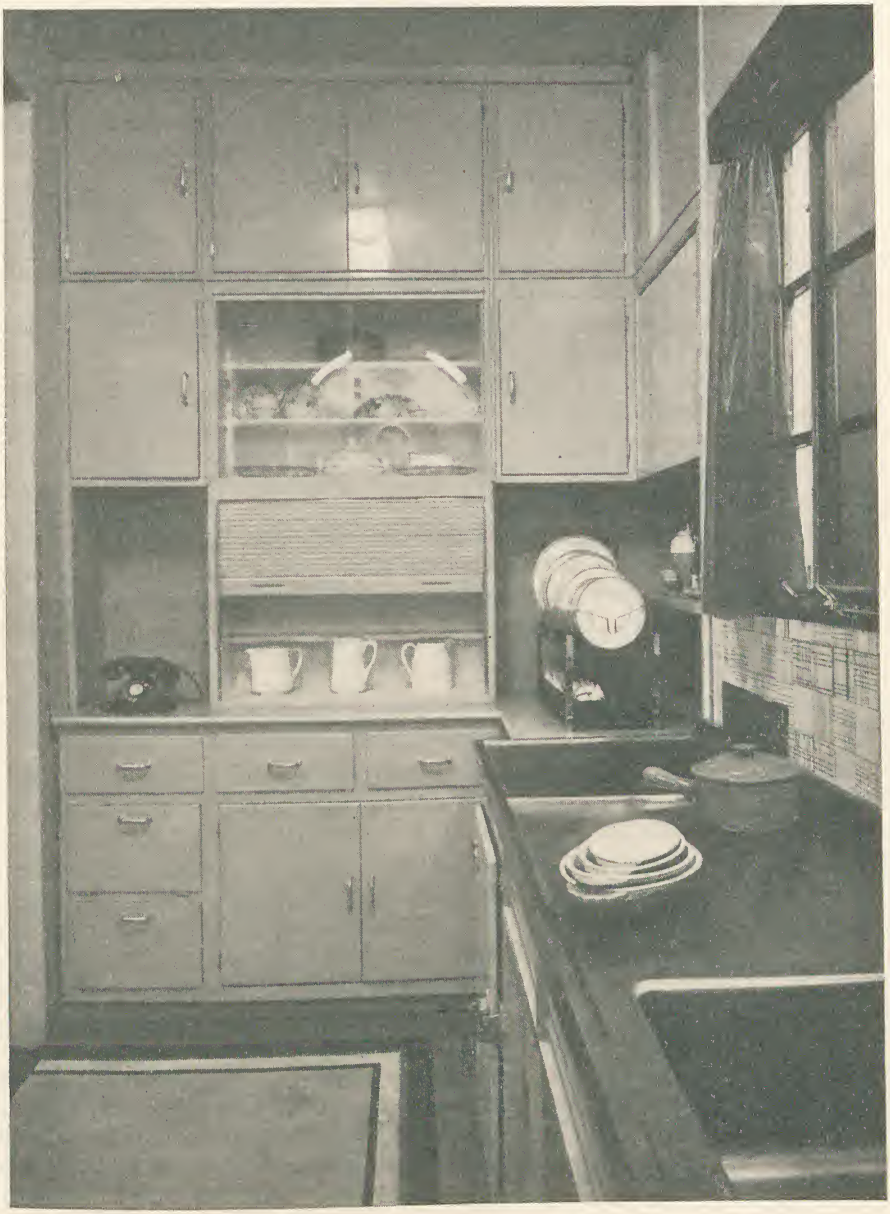


Fig. 4—A FITMENT FROM THE MODEL KITCHEN AT THE ROYAL ACADEMY INDUSTRIAL ART EXHIBITION, 1935, ENTIRELY COMPOSED OF A LIMITED NUMBER OF INTERCHANGEABLE BASIC UNITS

specialising in this work. Construction is generally of wood—the manufacturing costs of metal being too high for economic production as yet—and the finish is usually cellulose enamel, with chromium-plated or stainless-steel fittings. The design of such units, as the name implies, is based on the standardisation of dimensions to reduce cost by mass production, and to provide a range of sizes which can be made to fit, within a few inches, into any available wall space or recess.

Most standardised units fall into three categories :—

(1) Counter units, i.e. fitments such as undersink cupboards, vegetable and cake bins, pan cupboards, etc., about 3 ft. in height (working level), and 1 ft. 6 in. to 2 ft. in depth.

(2) Wall units, i.e. china cupboards and top cupboards, about 2 ft. in height by 12 in. in depth.

(3) Side units, i.e. larder fitments, broom cupboards, folding ironing-boards, etc., about 6 ft. to 6 ft. 6 in. in height, 1 ft. 6 in. to 1 ft. 9 in. in width, and of varying depth.

Standardised units are particularly valuable for use in kitchens for blocks of flats.

For certain individual jobs, however, it is sometimes desirable to design purpose-made cupboards instead of using pre-fabricated fitments. In such cases, it is first necessary to form a clear idea of the purposes for which the fitments are required, and also of the general sequence of work.

The Design of Cupboard Fitments

There are a few points which should be constantly kept in mind. A constant working level for counter tops, etc., must be maintained of about 3 ft. from the floor—minimum 2 ft. 10 in. Cupboards which are frequently used should not be placed too high or in difficult positions—cupboards for articles such as bottled fruits and preserves, which are required only at long intervals, can be placed near the ceiling. Handles to high cupboards should be placed near the bottom of the doors. Cupboard doors are best constructed of thick plywood or laminated board, which gives a flush finish, but they should be kept to within 5 to 6 sq. ft. in area, unless suitably braced or battened on the inside.

Drawers should be made to work on centre runners, and should not be generally of greater depth than 7 in., or of unmanageable width. They should not be placed at such a height that their contents cannot be easily seen by a small woman, or so low as to involve stooping. Cutlery drawers need to be divided into suitable sections, and lined with green baize.

The plinths of built-in fitments should be recessed—particularly at work centres—about 3 in., for toe space. When the fitments are not carried the full way up to the ceiling, in order to avoid a dust-trap at

the top they can be capped by a sloping or curved piece of three-ply, which can be easily dusted.

Secondary Items of Equipment

The following is a brief list of secondary, but important, items which should be given consideration in designing the kitchen :—

Plate Racks.—Can be either of wood—teak with birch dowels—or of metal; should be placed over draining-board to catch drips.

Tray Racks.—Important for larger kitchens; may be part of plate-rack, or in connection with service section.

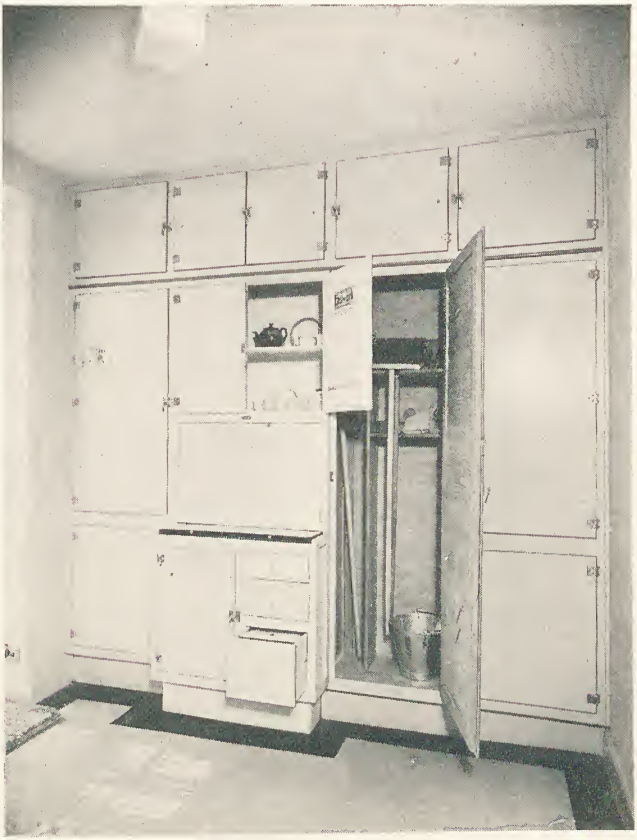


Fig. 5.—AN ASSEMBLY OF BUILT-IN STANDARD UNITS FROM A MODERN FLAT KITCHEN, INCLUDING KITCHEN CABINET, LARDER CUPBOARD, AND CHINA STORE

Housewife's Desk.—A fitment with accommodation for cook books, filing of accounts, etc.; telephone should be provided for.

Stool.—Suitable type similar to bar stool. Step stool, which is normally used as a seat for working at counter level, but which can be reversed to provide steps for reaching top cupboards.

Hot Towel Rail.—For drying tea-cloths.

Bell-indicator.—Best fixed over service door, or can be incorporated in fitment.

Clock and Wireless Loud-speaker.—Can be built into fitments.

Electric Plugs.—For toasters, percolators, iron, etc.

Trades Hatch.—In or adjoining back door, into which tradespeople can deliver goods during absence of owner or staff; automatic and self-locking; particularly suitable for flats.

MATERIALS AND FINISHES

Floor Finishes

There are two main types of floors—concrete and timber. Neither of these is satisfactory in itself, and needs to be covered by a finish that is hard-wearing, impervious to grease and water, and is easily cleaned.

The following are the principal coverings in present-day use, with notes on their respective characteristics :—

Wood Block or Hardwood Strip

Ordinary boarded floors are unsuitable for the kitchen, as they stain quickly, wear unevenly, and are difficult to clean, but it is still common to find hardwood floors specified on account of their appearance and because they are comfortable to walk on. Although better than floorboards, they are also not to be recommended, as they cannot stand up to the hard wear and are apt to swell with the dampness.

Jointless Composition

There are various patent composition floors, which can be laid in various colours and are pleasing in appearance. There are certain difficulties about the material, however, and the finished floor is apt to be noisy. Their chief advantages are that they are easily cleaned and are unaffected by water and grease.

Tiles

For many years, quarry tiles and, more recently, precast composition tiles, have been regarded as particularly suitable for the kitchen. They must be well laid, however, as the slightest unevenness will be a source of great annoyance to the cook.

Linoleum

A good-quality linoleum laid by cementing to the sub-floor is perhaps the best domestic kitchen floor covering. It is comparatively cheap, can be obtained and laid in a variety of patterns, and is hygienic and hard-wearing.

Rubber

Rubber flooring can be obtained in two forms—sheets, similar to linoleum, and in tiles. The former should be stuck to the sub-floor like lino, or it is liable to " creep " with wear. It has strong advantages in being waterproof, silent, and easy to walk upon, but is fairly expensive, and most colours of it show footmarks very quickly. It must be remembered, also, that it will not stand great heat, and must not be laid under or near boilers or cookers unless specially protected.

Rubber tiles have a rigid asbestos-cement core, and are keyed on the

under side, with the result that there is no lifting once they are laid. Their characteristics are similar to those of sheet rubber, but they probably wear longer.

Cork Tiles

Cork flooring is hard-wearing, and, when waxed and polished, is pleasing in appearance. It is comparatively noiseless, and easy to the tread. It is waterproof, and coved angles and skirtings can be obtained in order to make a really hygienic finish.

Wall Finishes

Wall covering for the kitchen should be durable, non-absorbent, and easily washed down.

Fig. 6.—A SIMPLE COMBINED LARDER, STORAGE, AND DRESSER FITMENT, SUITABLE FOR NEW WORKING-CLASS DWELLINGS

White or light-coloured tiling is probably the best material. Because of the cost, it is usually not possible to tile all the exposed wall surfaces, and common practice is to tile to a height of 4 ft. 6 in. from the floor level, and to paint the walls above with hard glossy enamel. It is essential to cover the areas immediately above the sink and around the cooker with tiles or similar material. Tiling should always return into window reveals, and should cover cills, so as to provide a useful shelf.

Washable wallpapers are sometimes used for the upper parts of the room, but are not especially recommended. Thin American cloth, however, which can be pasted on to the wall, is probably an alternative solution.

Methods of covering the walls by large sheets of asbestos-cement, bakelite finishes on plywood, or stainless metal, have been tried with

Fig. 7.—A SMALL COUNTRY HOUSE KITCHEN

Showing clean lines and attractive appearance. Another view is illustrated on the opposite page.

some success, but, apart from the expense, the chief difficulty is the covering of the joints, which rather spoils the smooth effect.

Hangings are obviously out of place in the kitchen, but curtains can hardly be dispensed with and they can be made part of the general scheme. They should be made of material unaffected by moisture or grease. Certain forms of processed silk or thin oilcloth are very suitable —they can be taken down and sponged clean when necessary, and replaced immediately. Cheerful plain colours or chequer patterns should be selected, of a light tone in order to lessen light obstruction.

Doors

All kitchen doors should be of the flush type, and should be painted in hard glossy enamel or covered with some durable material such as metal-faced plywood. All unnecessary mouldings and decoration must be avoided.

It is a good idea to allow the door to the servery to swing in both directions freely, so that it is possible for a person carrying a tray to

Fig. 8.—ANOTHER VIEW OF SMALL COUNTRY HOUSE KITCHEN
Note that the exposed walls are completely tiled and cove into the ceiling.

pass through easily. This type of door should have a metal kicking-plate. All kitchen doors require large finger-plates of stainless steel or similar material. Lever handles on the kitchen side are to be preferred, as they are easier to open with wet hands.

Windows

Whether the kitchen windows are of wood or metal will probably be decided by the design of the rest of the building, but, in either case, it is an advantage to dispense with all unessential glazing bars, which obstruct the light and make cleaning difficult. Care must be taken in the placing of the window that it is within easy reach for opening and closing, and it should be noted in this connection that the common practice of placing the sink under the window without due consideration is not to be recommended. It is sometimes necessary, however, to have the equipment immediately in front of a window, and cill heights should therefore be not less than 3 ft. 6 in.

If the lower part of the window, for the height of a normal pane, is made fixed, it is possible to use the cill as a shelf without interfering with the proper functioning of the window.

Particular care should be given to the painting of the window. Heat combined with moisture provides a most trying combination for both wood and metal, and, unless properly painted in the first place and periodically repainted, a wood window will warp and shrink and ultimately refuse to open, and a metal window will rust.

COLOUR

The most suitable colours are the quiet hues—sunny cream, primrose yellow, apple green, pale blue, and oyster grey. Individual preference determines the ultimate choice, of course, but, generally speaking, reds and oranges and dark tones should not be used except for little touches of interest and emphasis.

White, except for the ceiling, is also unsuitable for the kitchen in large areas, and an all-white room is rather cheerless.

There should never be more than two principal colours in the decorative scheme, and of these, one should be definitely dominant and the other the contrast. For example, walls, tiles, and equipment might be cream, with curtains and cupboard handles, say, green.

Interesting and decorative use can be made of metal tiles, coloured glassware, and pottery.

Floors should be fairly dark, but they can be made interesting, when in lino or rubber, by inlaid meander or geometrical patterns.

LIGHTING

Natural Lighting

The arrangement of windows must provide for abundant natural light. A diffused adequate light over all parts of the room is the ideal to be aimed for, and care must be taken to avoid dark corners. Side light is better than top light, but lanterns should be used if there is no other way of ensuring a naturally well-lighted kitchen. It is particularly important that the special work areas—sink, cooker, and table—should have as much light as possible, and the layout of the equipment must be borne in mind in placing the windows, and vice versa.

Artificial Lighting

The artificial lighting of the kitchen should, as far as possible, be arranged to give the effect of daylight. Usually, in a small kitchen a centre ceiling-point of sufficient intensity will, assisted by the highly glazed finishes of the walls and equipment, provide adequate illumination for working purposes. It is very desirable, however, to supplement the general lighting of the room by bracket or wall lights over the sink and cooker.

Light Fittings

Light fittings for the general illumination of the kitchen should be of the semi-indirect type—that is, with the lamp totally enclosed by a

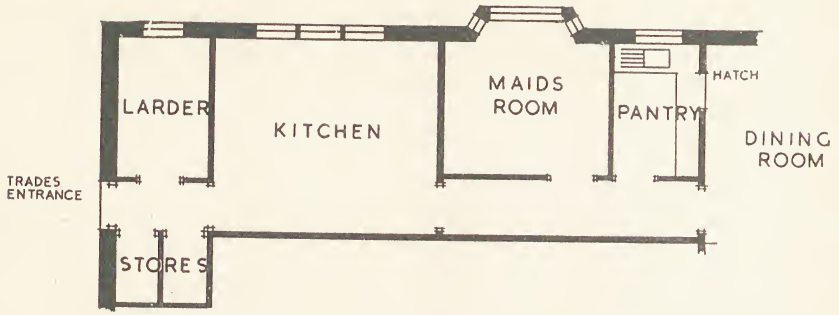


Fig. 9.—A SUITABLE ARRANGEMENT OF DOMESTIC QUARTERS FOR A COUNTRY HOUSE

cube or sphere of opal glass. It is important that the fitting should be unaffected by moisture. The light should be near the ceiling, so that the maximum reflected illumination is obtained from it.

Supplementary light over the working areas should be arranged to illuminate them without causing glare to the cook's eyes. Fittings similar to the adjustable reading-lamp have possibilities.

VENTILATION

It is of great importance that the kitchen should be well ventilated in such a way that cooking odours are drawn away and dispersed where they will not cause annoyance. In the case of natural ventilation, the direction of the air currents must be carefully studied to make sure that there is no danger of smells penetrating to the living-rooms.

The cooker is the chief source of trouble, and provision should be made for carrying away its fumes and steam as quickly as possible. The simplest method is to provide a canopy, height about 6 ft. 6 in. from the floor, extending well over the boiling-plate, so constructed that it leads the rising hot air currents to the outside through a ventilating grille or by means of a flue.

In internal and very small kitchens in flats and in some large kitchens it is necessary to supplement natural ventilation by artificial means. This is usually done by means of an electric fan. The best type to employ is the kind with the completely enclosed motor, which is silent in operation. Models are now available which can be built into the wall or fixed to the window glazing without looking unsightly.

VARIOUS TYPES OF KITCHENS

Kitchens for Flats

In flats, considerations of space are the governing factors in design. Although there has been some reaction in recent times against the impossibly small kitchen, particularly to be found in converted work,

it is still imperative that there should be absolutely no wasted space. It is also important that kitchens for new blocks of flats should be completely equipped and well designed, because of the consequent letting value.

Very Small Kitchens

For one- or two-roomed flats which are intended only as a *pied-à-terre* for tenants who do not require to cook more than the very simplest meal, it is common to plan the kitchen in the form of a recess off the living-room. The essential equipment comprises a table cooker, sink, and very small refrigerator, with as many cupboards and shelves as can be accommodated.

Fig. 1 shows a kitchen of minimum dimensions, which is nevertheless quite satisfactory for simple meals for one to three persons.

Figs. 2 and 3 show kitchens of slightly larger dimensions, which are quite capable of dealing with the ordinary daily needs of two to four persons. These types are usually entered from the hall of two- or three-bedroom flats.

It is not necessary in such very small kitchens to keep strictly to the sequence of operations, as all the equipment is very close together. Note, incidentally, that all the equipment is ranged against walls. No space is wasted, and only the minimum amount of free space necessary for one person to work in is left.

For Larger Flats

For larger flats, the size of the kitchen increases, and planning is on similar lines to that for the small house. There are, however, certain points to be borne in mind in dealing with all flats. Refuse disposal must be considered, and provision made for dealing with the daily quantity. The usual method is to provide a hygienic receptacle sufficient to hold one day's amount, which is put in a two-way cupboard with a door on to the public corridor or balcony, whence it is removed, emptied, and replaced by the porter every morning. The use of chutes will probably grow in the future.

Except for large flats, a separate larder is an unnecessary waste of space. A fitment, suitably ventilated to the outside air, takes its place, giving equal storage in less area, but, in all flats, a refrigerator is essential, and this should be built into the fitment.

Top cupboards, close to the ceiling, are probably of more use in the flat than in any other type of kitchen. A long cupboard for brooms and brushes, etc., and a fitment incorporating a folding ironing-board, are also necessary in addition to the cooking equipment.

Tradesmen's hatches, as mentioned previously, are frequently included in flats.

Fig. 10.—THE KING'S HOUSE AT BURHILL—THE MAIN PART OF THE KITCHEN

In the main part of the kitchen, ample space has been allocated for the electric cooking stove with hot plate adjoining, while immediately under the window is arranged a large work-table.

The kitchen walls are tiled for the full height, the ceiling being painted with a protective rubber paint. The scullery section has been formed in a recess, and in addition to the teak sink a large teak drainer-board is provided. The space under the sink has been utilised for cupboard space. On one wall of this section a special heated cupboard is provided for drying and airing towels. A plate-drying rack is fixed above the sink.

A large, well-ventilated larder opens out of the kitchen, and a refrigerator is provided, with a store cupboard over. Ample storage cupboards are provided for hardware and china. The service pantry adjoins the dining-room and kitchen. Ample cupboard storage has been provided for glass and china, and special lined cutlery drawers are fitted. (*Architect : C. Beresford Marshall, F.R.I.B.A.*)

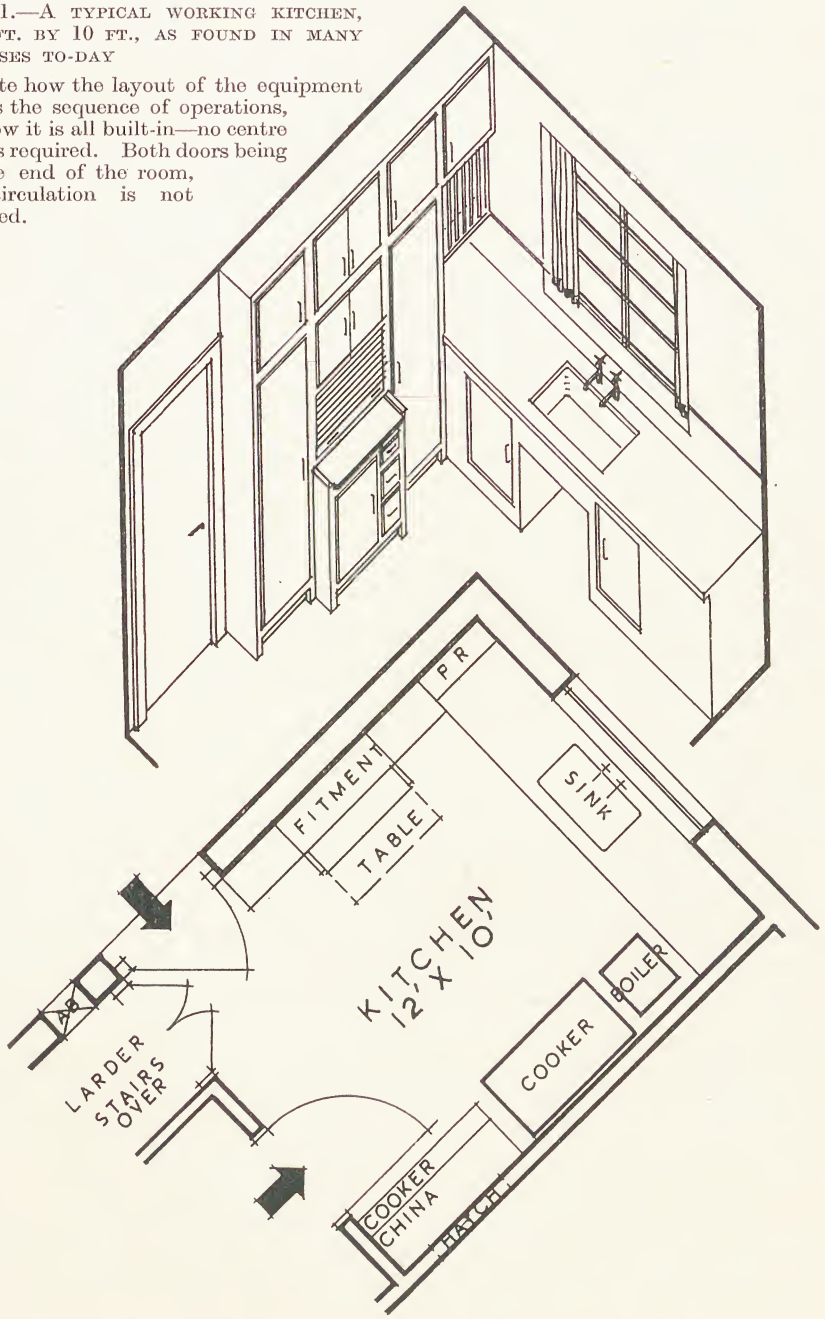
Working-class Flats

The kitchen equipment for working-class flats is subject to special influences, the most important being the cost. Any attempt to provide built-in fitments of the ordinary kind is usually defeated by the consideration of expense, despite the savings effected by standardisation.

It is possible, however, to reduce costs by modifications in design. For instance, backs, sides, and tops of cupboards can be omitted where they abut against finished walls or ceilings. This, in itself, is desirable from the hygienic point of view. The proportionate numbers of doors and drawers can be reduced, and cheaper grades of timber and fittings

Fig. 11.—A TYPICAL WORKING KITCHEN, 12 FT. BY 10 FT., AS FOUND IN MANY HOUSES TO-DAY

Note how the layout of the equipment follows the sequence of operations, and how it is all built-in—no centre table is required. Both doors being at one end of the room, the circulation is not confused.



can be used. Enamelled finishes can be replaced by staining and synthetic lacquer.

Another special point about this class of work is the advantage of providing slatted wood or wire-mesh shelves, resting on battens, in the cupboards, which can easily be removed for cleaning. In the case of a long cupboard, if the door is made to finish about 3 in. short at the bottom, and the flooring is carried through, it is possible to sweep it out with a long broom when the shelves are removed.

Separate larders are particularly wasteful as supplies are, more or less, obtained from day to day, and the accommodation required is not great.

Country House Kitchens

In dealing with kitchens for large country houses, restriction of space is no longer an important factor in design. The principal point to ascertain at the outset is the extent and nature of the catering requirements, and the number of staff involved. Meals are, generally speaking, on an altogether larger and more varied scale, and the working routine is in a different category.

Although the essential sequence of operations remains the same, it may be necessary to duplicate or supplement each unit. Separate sculleries for kitchen utensils and for table ware may be necessary, and working centres and cabinets vary according to the number of cooks.

Important points to be borne in mind in the planning are :—

Provision of ample larder and refrigerator accommodation—particularly in cases where quantities of game are periodically stored.

Housekeeper's office—which may be a screened-off portion of the main kitchen.

Servants' hall—in accordance with the number and classes of servants.

Butler's pantry—fitted with baize-lined cupboards and drawers for silver and glassware, probably including small teak sink and safe.

Wine store—with small refrigerator.

Ample table-linen store.

All cupboard fitments and equipment should be of the best quality. Service corridors should be wide. For service on upper floors, a small goods lift should be arranged, communicating with a service room having accommodation for china and cutlery, sink and drainer, small refrigerator, and space for a trolley.

Small-house Kitchens

Kitchens for small houses vary tremendously. Often they are well planned and equipped, but others, at no less cost, are badly conceived, without any understanding on the part of their designers of the fundamentals of kitchen planning.

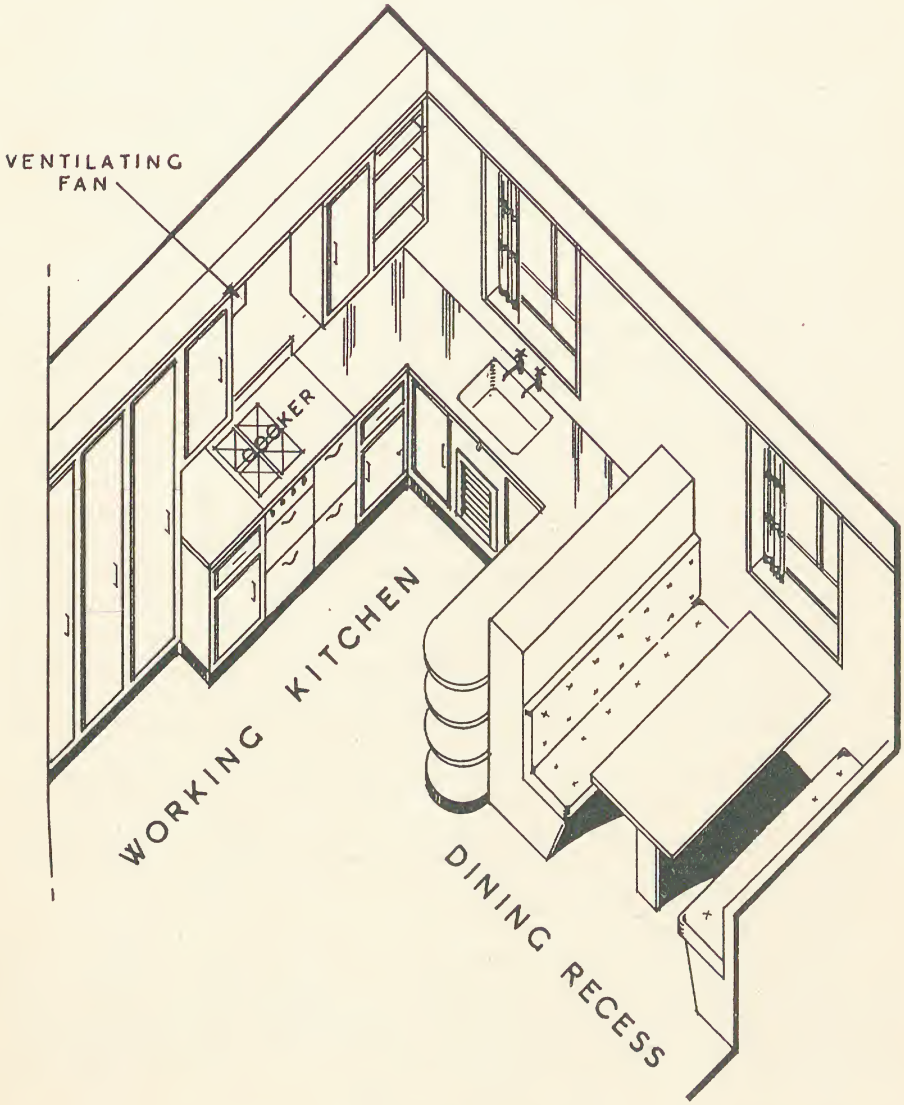


Fig. 12.—A SOMEWHAT LARGER KITCHEN

Showing how an attractive dining-recess for maids or breakfast nook for the family can be formed by the arrangement of the fitments. Note the continuous working top.

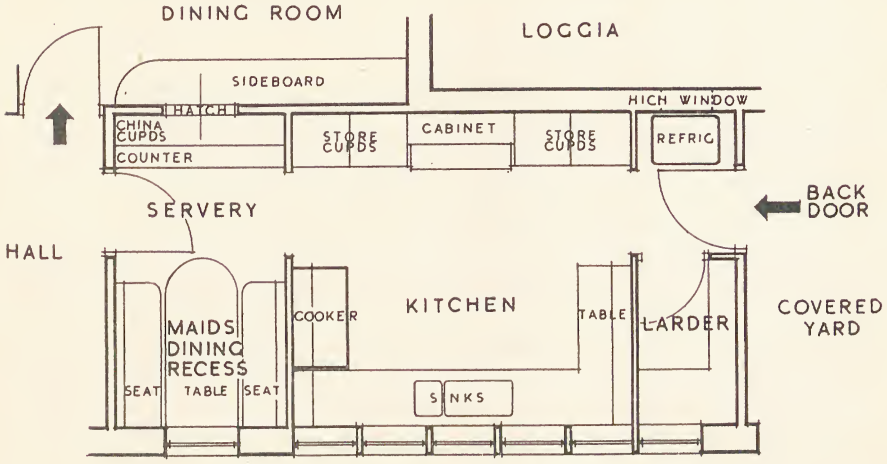


Fig. 13.—A KITCHEN FOR A £2,000 HOUSE WITH TWO MAIDS

Note the simplicity of the circulation, the continuous line of fitments, and the separate recess for the maids combined with the servery.

Examples of various types of small-house kitchens are shown in Figs. 11 to 13.

Fig. 11 shows a typical working kitchen, 12 ft. by 10 ft., as found in many houses to-day. Note how the layout of the equipment follows the sequence of operations, and how it is all built-in. No centre table is required. Both doors being at one end of the room, the circulation is not confused.

A somewhat larger kitchen is shown in Fig. 12. Note the continuous working top. This also shows how an attractive dining-recess for maids or breakfast nook for the family can be formed by an extension of the room.

Fig. 13 shows a kitchen for a £2,000 house with two maids. Note the simplicity of the circulation, the continuous line of fitments, and the separate recess for the maids combined with the servery.

SANITARY SCIENCE APPLIED TO BUILDING

PART IV.—TREATMENT OF WALLS AND FLOORS

REFERENCE has been made to soils, sites, dampness, roofing, and gutters. In the general construction and equipment of buildings, from a health point of view, consideration must be given to many other details of paramount importance, and these include walls, floors, and windows.

Absolute dryness is essential for a healthy building, and this can be assured only by proper planning and design, the use of good-quality materials, and efficient workmanship.

Walls

All walls, whether of solid or hollow construction, and including those for forming partitions, should be soundly constructed. With regard to cavity walls, it has been stated that this type of wall is suitable for damp positions, and if they are properly formed this statement is quite correct ; but unless due care is exercised in their construction they may prove to be a source of trouble, by failing to produce the result for which they are intended, and that is to keep a building dry and warm. Those responsible for the proper construction of the walls should ascertain that the space is not reduced by the squeezing out of mortar from the joints, which may result in a considerable reduction in the width of the cavity. Both internal faces should be properly struck as the work proceeds. Mortar droppings must not be allowed to remain within the cavity, and provision must be made for their periodical removal from the base of the cavity during construction, by leaving out a brick or bricks at intervals in the wall to permit of this being done. These bricks should not be built in until the wall is complete.

Weep Holes

In order that moisture may escape from the base of the cavity, weep holes should be formed at intervals along the base of the wall. This may be conveniently arranged by leaving a few open vertical joints in the brickwork.

Thickness

In some classes of work, hollow or cavity walls are formed with two thicknesses of $4\frac{1}{2}$-in. work, with a $2\frac{1}{2}$-in. cavity ; whilst in others, a $4\frac{1}{2}$-in.

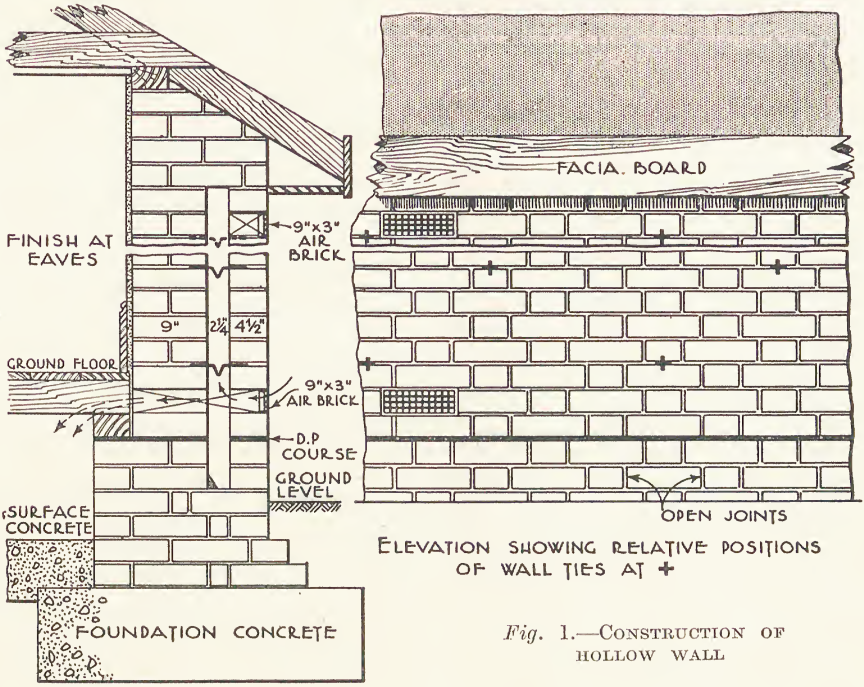


Fig. 1.—CONSTRUCTION OF HOLLOW WALL

skin and $2\frac{1}{4}$-in. cavity are formed outside the ordinary wall thickness (Fig. 1). The thicker portion should always be formed on the interior, to give proper support to floor and roof timbers. No woodwork should be fixed in the outer skin, as this is liable to be damp. Where brick panels are formed on upper floors between concrete piers, two thicknesses of $4\frac{1}{2}$-in. work, with a $2\frac{1}{2}$-in. cavity, are often used, as they are simply a filling and do not support any weight. The concrete floor is continued to the outer wall face to form a continuous lintel, and upon this lintel the work is supported. At the base of the cavity a fillet is formed, and this in turn is covered by a 4-lb. sheet-lead apron, as shown in Fig. 2. The apron is continued to the outer face of the wall, and weep holes are left in the brickwork, as previously described. Where windows or doors occur, a sheet-lead or copper apron or cover piece should be provided over them, to prevent any moisture within the cavity coming in contact with the woodwork.

Ventilation

The cavity between the walls must be well ventilated by providing a suitable number of air bricks at the base and the upper part of the wall.

Bond

The 4½-in. thickness in cavity walls is sometimes carried out in Flemish bond, using snap headers (i.e. a stretcher or full-length brick halved), or in stretcher bond. The use of the former method sometimes gives rise to short headers being inserted, whereas with stretcher bond the full thickness is maintained throughout.

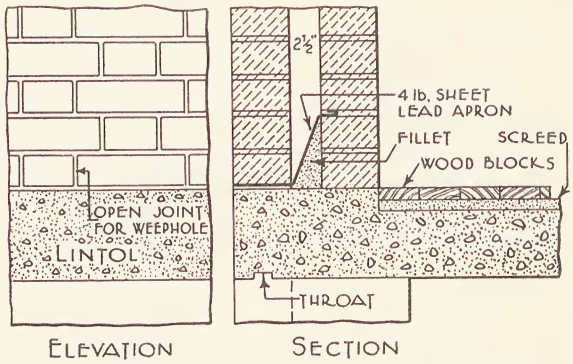


Fig. 2A.—CAVITY WALL AT FIRST FLOOR

Construction of panels between concrete columns. Lead apron piece over continuous lintel at first-floor level.

Wall Ties

If iron ties are used they should be well galvanised, for preference. If of plain iron they should be coated with tar, or if desired they may be tarred and coated with fine sand as a protection against corrosion.

These ties are of various types, and a useful pattern is shown in Fig. 3, which has a V-shaped depression in the centre ; others are formed with a double twist, the object in each case being to prevent the passage of moisture to the inner wall. In place of iron ties, purpose-made bricks or glazed-stoneware ties are often used.

In fixing iron ties, they must not tip inwards, as moisture may travel along them to the inner wall.

Spacing

Ties should be spaced about 3 ft. apart horizontally, and every four courses of brickwork vertically, and arranged alternately, as shown in Fig. 1.

Partition Walls

For hygienic reasons, partition walls should be solid. Lath and plaster partitions are not to be recommended, and are little used at the present time.

If a wood-framed partition is desired or required, for any particular reason, the covering should be of a suitable material which is vermin-proof and sound-

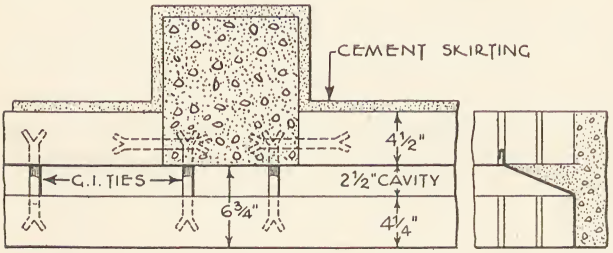


Fig. 2B.—SHOWING COLUMN AND RELATIVE POSITION OF TIES

resisting. The latter item in the construction of partition walls is one that is sadly neglected in many of our buildings, and especially in the case of walls separating sanitary apartments from living-rooms, etc. Sanitary by-laws stipulate that such walls shall be solid, and providing that the requirements of the by-laws are complied with as far as a solid wall is concerned, little or no thought is given to its sound-resisting qualities. The results of such construction, if not unhealthy, are unpleasant, and are not conducive to the acme of comfort that is a desirable quality of an ideal dwelling-house, equally as much as the bathroom with the elaborate panel front to the bath, which panel often conceals many faults such as unfinished plaster work, unfinished floors and walls, and inferior plumbing work.

Face of Walls

The ideal type of wall face is undoubtedly one that is designed to contain as few projections and ornamental features as possible, so that lodgment of dust, etc., is reduced to a minimum. This is to a great extent the principle of modern construction and design for both exterior and interior walls, and from a hygienic point of view is to be commended. The old-style type of wall face, with its enrichments and heavy mouldings, formed ideal breeding-grounds for micro-organisms in the many dust-harbouring crevices which the style created.

Fig. 3.—IRON V-TYPE WALL TIE

Angles of Walls

In buildings such as hospitals and similar institutions, where cleanliness is an indispensable condition, all angles should be formed with a radius to prevent lodgment of dust, and to facilitate cleaning (Fig. 4).

Wall Finishes

Various materials and methods are available for wall finishings, according to the class of building and the purpose for which it is to be used. For many purposes the wall finish needs to be formed with material of an impervious character. For the general run of ordinary buildings, the plaster-faced wall is still very much in evidence, and with the use of proper materials a perfectly smooth surface can be obtained which may afterwards be treated in a variety of ways.

Non-absorbent Surfaces

In dwelling-houses it is desirable to provide a non-absorbent wall surface to many apartments, such as sculleries, bathrooms, w.c.s, pantries,

housemaids' closets, etc. The usual method is to face the walls with tiles, and in some instances to form the inner face of the walls of glazed bricks. For better-class work a facing of real or imitation marble or glazed panelling is adopted. The objection sometimes raised to non-absorbent wall surfaces is that condensation of moisture so easily occurs, especially in bathrooms, sculleries, and kitchens, where steam is passed into the air from the opening of hot-water taps or from cooking operations ; but from a sanitary outlook, the advantages of such a surface offset the objection. Proper ventilation arrangements will greatly help to overcome the condensation difficulty.

In large establishments, such as office blocks, factories, and similar buildings, the faces of walls of sanitary and washing apartments should be formed of non-absorbent materials, as they are more sanitary and facilitate cleaning. In abattoirs and various other types of premises where foodstuffs are prepared or manufactured, it is essential that walls are faced with non-absorbent materials.

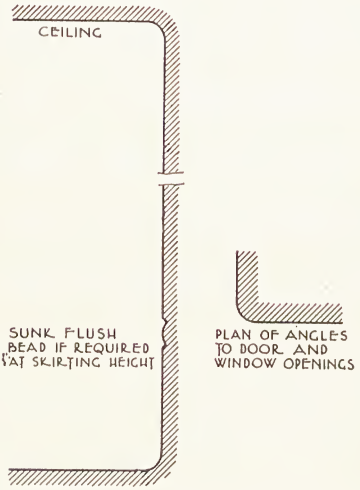


Fig. 4.—FORMATION OF COVED ANGLES

Painted Walls

Plastered walls properly prepared and coated with oil paint form a very good surface, and they may be designed and finished in a variety of styles to blend with any class of decorative scheme. Painted wall finishes are adopted for many apartments both large and small. They form a sanitary, non-absorbent surface, are readily cleansed, and will permit of repeated washings before repainting is necessary. Painted walls have in many instances been replaced by the use of tiles, but enamel and varnished surfaces for walls are still often used.

Distempered Walls

Washable distemper, or " water paint," is also a sanitary material, and as it is readily cleaned it is to be preferred to ordinary distemper made up with size. If washable distemper is properly applied it provides a sanitary wall surface, and it should be noted that to obtain this result the maker's instructions should be strictly carried out.

Papered Walls

Papered walls still continue to be greatly in favour as a decorative medium. From the hygienic point of view no great objection can be raised to the use of wallpaper provided that the walls are properly con-

structed and faced, also that due care is given to the preparation before paper-hanging is commenced. Certain objections may be raised against the use of papers having rough surfaces, to which matter may adhere, and it is sometimes suggested that papers of a "sanitary" type should be adopted or that paper should be varnished to give a non-absorbent surface, but from a purely decorative point of view this is out of the question, except in the case of sanitary apartments or similar places where a non-absorbent surface is required. Whatever type of paper is used, periodical cleaning should be carried out, as dust and filth will collect as it will on other wall surfaces such as painted or tiled walls, especially at the upper portions, which are out of ordinary reach. The great objection to the use of wallpaper from a sanitary point of view would appear to be not so much to its use in new well-constructed buildings, but when the time arrives for the renewal of the wallpaper and fresh paper is placed over the old, soiled material.

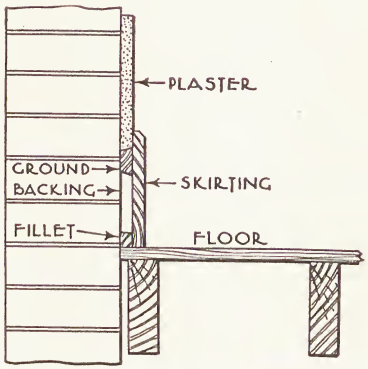


Fig. 5.—SKIRTING FIXED TO PROPER GROUNDS

This section is not dealing with the renovation of old buildings, but from a sanitary standpoint a reference should be made to the repapering process in that :—

All old paper should be removed completely from the walls, the latter then being thoroughly washed with a mild disinfectant before new paper is hung. The practice of covering old, soiled paper with new is most insanitary, and is to be condemned. The use of wallpaper as a mask for defective plaster work should not be permitted, and all defective plaster should be cut out and properly repaired. Decomposing paste, cracked plaster, and the filth on old paper, when such is covered with new, are all conducive to the presence of vermin.

Where wood skirtings are to be used, proper grounds should be provided and the walls plastered before the skirting is fixed. In many cases, small pieces of batten are nailed to the brickwork and the skirting fixed to these before plastering is commenced ; the result is that the space between the back of the skirting and the brickwork is left when plastering is completed. After a time the plaster breaks away along the top edge of the skirting, leaving gaps into which dust and dirt can pass into the space referred to, and this greatly favours the presence of vermin (Figs. 5, 6, and 7).

Floors

Various types of floor are formed, and these vary in accordance with the class of building. From a sanitary point of view, floors should be free

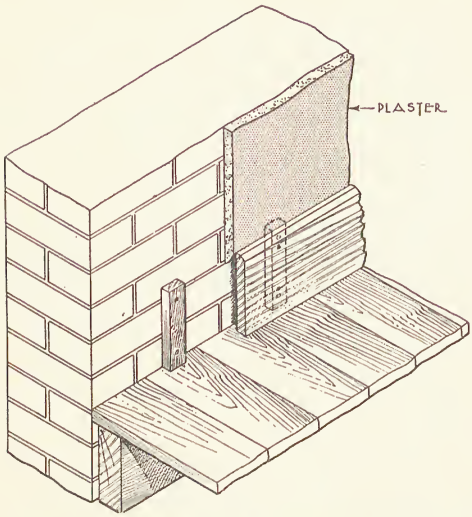


Fig. 6.—IMPROPER FIXING FOR SKIRTING

from crevices in which dust and dirt can collect, and from openings through which such matters may pass. The surface should be capable of easy cleaning. What may be termed solid floors are the best, such as those constructed of reinforced concrete, or one of the many types of patent flooring, and covered with narrow boarding, wood blocks, or jointless floor material, but in many cases the cost of this type of floor is prohibitive. The ordinary wood floor composed of boarding laid on joists is still very much used, especially in the smaller class of building. The wood used for this type of floor should be thoroughly "seasoned" before it is used, to avoid subsequent shrinkage. Many floors of this type develop open joints due to shrinkage of the boards, even though they were cramped tightly together when laid; these open joints soon appear when the boards are put down in a more or less "green" condition, and such openings form passages for dirt, dust, and floor washings, and in the case of ground floors allow draughts to pass easily into the rooms. Grooved and tongued, rebated, and similar joints are to be preferred where boarded floors are desired, but these boards require to be well seasoned before use (Fig. 8).

Ground Floors

Following the provision of surface concrete and efficient damp-proof courses, a joist and boarded floor at ground level should be formed well above the surface of the concrete, and arranged so that proper through ventilation of the space between floor and concrete can take place. A suitable number of air bricks should be provided for this purpose, and these should be placed as high as

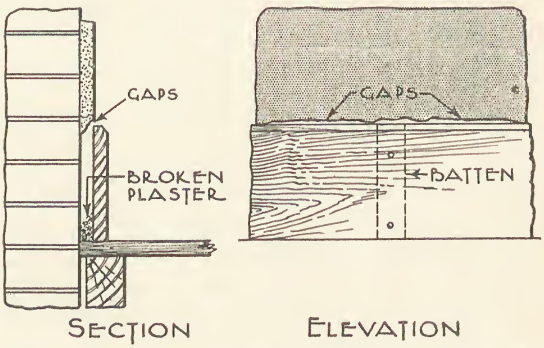


Fig. 7.—THIS SHOWS WHAT OFTEN OCCURS WHEN SKIRTING AND PLASTERING ARE CARRIED OUT AS SHOWN IN FIG. 6.

The plaster breaks away and falls behind the skirting, as shown.

possible to prevent the likelihood of their being covered with earth, which might happen where flower beds are formed against the wall of a building. If iron air bricks are used they should be galvanised. Absence of ventilation beneath ground floors of this type gives rise to various troubles, such as foul smells and dry rot. If the latter should occur, it is quite possible for it to reach the first floor, travelling via skirtings, window linings, etc., and much damage may result from this cause.

Sleeper and Other Walls

Sleeper walls for supporting the floor joists should be constructed on the honeycomb principle, to permit of free air movement through them. If partition walls are built up from the concrete, suitable openings should be left in them, for the same reason. This may be accomplished as shown in Figs. 9 and 10.

Impervious Floors

For sanitary purposes, floors of an impervious, i.e. non-absorbent, type are necessary for many apartments, and in the ordinary dwelling-house it is the usual practice to provide this type of floor to such apartments as sculleries, larders, pantries, housemaids' closets, outside water-closets, and in some instances the kitchens. In better-class property the bath-rooms and inside w.c. apartments are often provided with impervious floors, but it is not the general practice. It would be a good plan if impervious floors were generally adopted for all sanitary apartments in all classes of buildings. This is especially applicable to water-closet apartments, as complaints of foul smells in such places in comparatively new buildings have been found to be due to the accumulation of moisture between the floorboards and the floor coverings, and in some instances the boards have been found to be saturated with moisture of a foul-smelling character. In bathrooms, where splashing of water is practically unavoidable, an impervious floor is a valuable asset, in addition to being more sanitary and easily cleaned. In buildings such as those of an industrial character, hospitals, institutions, etc., the provision of impervious floors for many purposes is essential, and further comment is unnecessary. The many types of impervious flooring materials available gives one a wide range of choice, and they may be obtained to tone with various decorative schemes if desired.

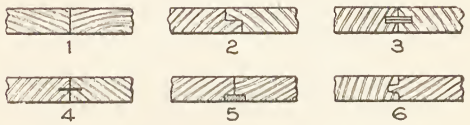


Fig. 8.—TYPES OF JOINT USED IN FLOORING

1. Butt or straight joint. 2. Rebated joint. 3. Grooved and wood tongued. 4. Grooved and iron tongued. 5. Filleted joint. 6. Matched joint.

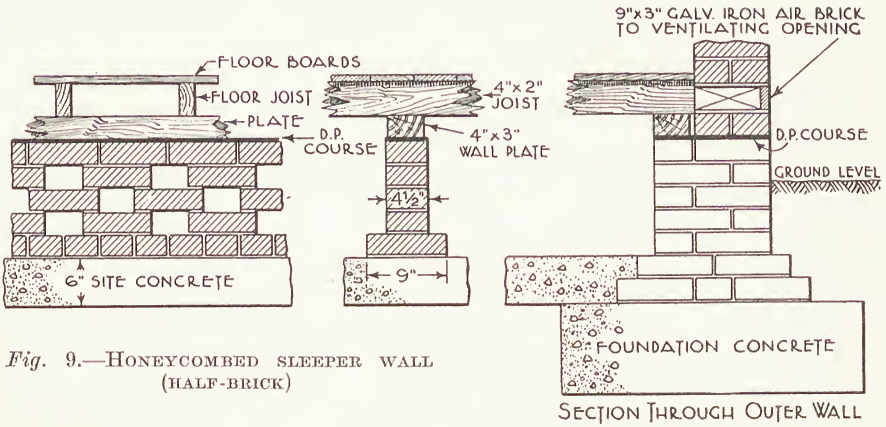


Fig. 9.—HONEYCOMBED SLEEPER WALL (HALF-BRICK)

Wood Blocks

These form an excellent floor surface, and are often used for the ground floors of dwelling-houses. They are usually laid on concrete, the surface of which has been floated with cement and sand or fine concrete struck off from screeds to a level surface, the blocks then being laid in a bedding of mastic (Figs. 11 and 12).

Parquet

A surface of parquet is another good floor material, and provides a sanitary covering in addition to its decorative qualities.

Rubber

Another type of floor covering or surfacing is formed of rubber, which may be applied in stout sheet form or laid in a mastic condition. It is suitable for many classes of buildings, and is sanitary and resilient, and noise due to traffic over it is greatly reduced.

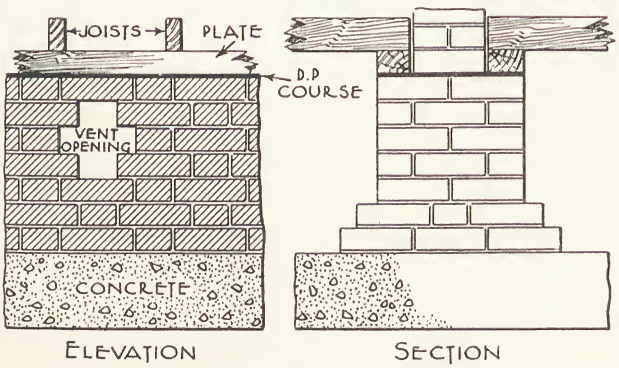


Fig. 10.—ARRANGEMENT OF VENT OPENINGS IN WALLS CARRIED BELOW FLOOR LEVEL

Ceilings

The type of ceiling adopted for various buildings depends upon many factors, such as the method of construction of the fabric, and the use for which any apartment of a building

is required. The plastered ceiling is still extensively used, whether upon a solid foundation or upon laths fixed to wood joists. Metallic lathing is now much used, and is advantageous in that it does not rot, neither does it harbour vermin. From a hygienic point of view consideration should be given to the prevalence of extensive ornament, which tends to harbour dust, the type of surface which is adopted, and the materials used in decorating. Another important factor is the effect of noise upon the health of the occupants of buildings such as offices, schools, etc., and in this respect much care has been given to the formation of ceilings which greatly reduce noise by introducing materials of a sound-absorbing character, which at the same time are capable of decorative treatment, and also possess valuable acoustic properties. Modern practice has done much to avoid a great deal of ornament, and many advantages may be claimed for the plainer type of ceiling from a sanitary point of view.

Windows

An abundance of natural light in a building is necessary for the well-being of the occupants. A badly lit room, staircase, or passage-way leaves much to be desired. Natural lighting, whether of a direct or indirect character, is important, and should be given due consideration when designing a building, so that windows are of a suitable size, and so placed as to give good lighting to the interior. The efficient lighting of a building by natural as well as artificial means is an important part of the architect's business.

Certain minimum requirements are laid down in respect of the amount of window area in proportion to the floor area or cubic content of the room, such as, the window area shall be equal to one-tenth of the floor area, or there shall be 1 sq. ft. of window area to every 100 cu. ft. of space ; that one-half of the window shall be made to open. There are also other methods of arriving at the required amount of window area given by various authorities on building. These are guides for minimum requirements, but in order to get good lighting it may be necessary to fit larger windows than those given by these figures. By the first rule, if we assume a room with a floor area 16 ft. by 12 ft., it would require window area equal to $\frac{16 \times 12}{10} = 19\frac{1}{5}$ sq. ft., or approximately 5 ft. 6 in. by 3 ft. 6 in. By the second rule, assuming the room is 9 ft. high, the window area would be equal to $\frac{16 \times 12 \times 9}{100} = 17\frac{7}{25}$ sq. ft., or approximately 5 ft. 6 in. by 3 ft. 2 in. For the efficient lighting of a room of the size given, these window areas are insufficient. Another factor which must be considered is the cooling effect of glass, as a large window area will have a distinct influence on the temperature of a room during the cold weather, and may give rise to difficulty in keeping the room suitably warmed by ordinary

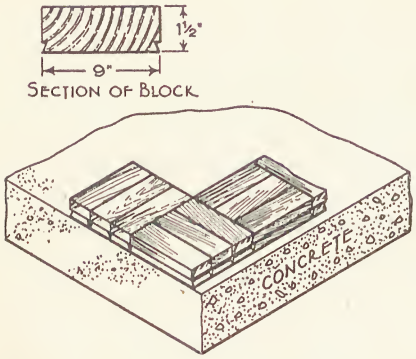


Fig. 11.—WOOD-BLOCK FLOORING LAID ON MASTIC AT GROUND-FLOOR LEVEL

means; this cooling effect will also be influenced by the aspect of the room, and the wall in which the window is situated. Modern methods of heating usually overcome this, and where central heating is adopted due allowance is made for the extra cooling influence of glass and also walls in exposed positions. For rooms in basements, narrow courts, or in the wells of tall buildings, it is not always possible to obtain direct lighting from the sky; for such rooms recourse must be had to reflected or refracted natural light. This is sometimes effected by the use of reflectors or prismatic lights, and to assist the reflection of light into many rooms of the type mentioned, the walls opposite to them, in the wells of tall buildings and in narrow courts, etc., are usually faced with white-glazed bricks. Even in spacious areas enclosed by three or four blocks of buildings, the walls are faced in this manner, which adds greatly to the amount of light available.

Glass

The rays of heat and light from the sun contain what are known as ultra-violet rays. These rays possess certain properties of a health-giving character, and the community are advised to avail themselves of these rays whenever possible.

The passage of these rays does not take place through ordinary common glass, but "Vita" glass possesses properties which permit the passage of these ultra-violet rays, in addition to ordinary light-rays. Many buildings of the domestic and industrial type have windows fitted with "Vita" glass, to the benefit of the occupants.

Artificial Lighting

In the lighting of interiors by artificial means, whether the illuminant be gas or electricity, direct glare should be avoided. Naked or unscreened lights are harmful to the eyes. Diffused light is less harmful, and intense shadows due to strong glare are greatly minimised. Walls and ceilings play an important part in the amount of reflected, diffused, light which they give off, and the amount varies according to the colour and nature of their surfaces. Due consideration should be given to this matter in arranging the lighting of interiors.

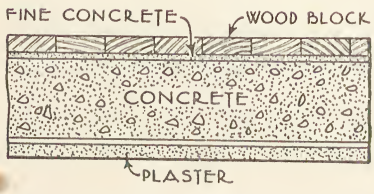


Fig. 12.—WOOD BLOCKS ON CONCRETE FOR UPPER FLOORS

WATER-SOFTENING APPARATUS AND INSTALLATION

THE architect or builder is frequently called upon to make provision for the installation of a water softener in planning a residence or block of flats, and his advice is required in regard to a suitable size and make.

How a Typical Water Softener Works

Domestic water softening is accomplished by the " base exchange " method, i.e. the bed contained in the softener gives up its sodium content in exchange for the calcium, magnesium, and other hard scale-forming salts which constitute the hardness in water. As all the salts of sodium are soluble, by this exchange no hard salts are left in the water.

Regenerating the Softener

When the sodium content of the bed has been exhausted, a solution of common salt is passed through it. Exactly the reverse action then takes place. The bed releases the hard salts it has absorbed, and in exchange takes up the sodium content of the salt. It is thus restored to its original state. The whole of the water passing through the softener during this period of regeneration flows to the drain. The softener is then again ready to provide the quantity of softened water stated by the manufacturers according to its type and size.

Effect of Softening

The water resulting from treatment by the " base exchange " method is of zero hardness. This is desirable and eminently suitable for all domestic purposes. It has no harmful effects upon copper, lead, or galvanised pipes and cisterns. Copper back-boilers can be installed in districts where the hard water has been treated by the base exchange process. Corrosion and " pitting " of pipes and boilers can occur with naturally " soft " waters from peaty moorland districts which contain humic acid, and with waters containing iron salts in any quantity. Frequently rain-water in industrial districts will indicate acidic properties due to absorption of atmospheric gases. These waters have a solvent or corrosive effect upon metals, particularly boilers, and in all cases of doubt or suspected presence of corrosive waters the makers should be consulted.

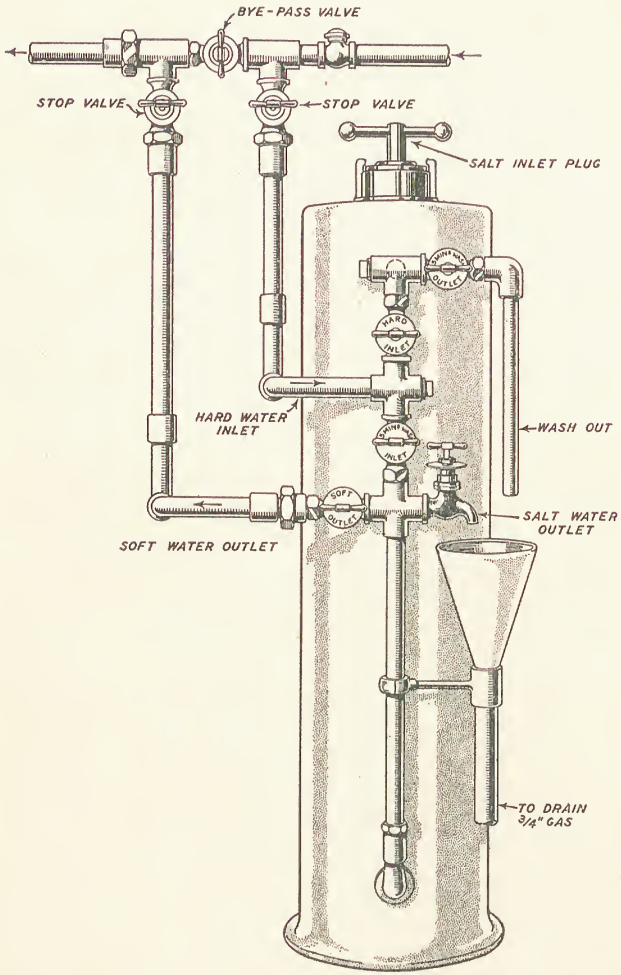


Fig. 1.—TYPICAL "BASE EXCHANGE" DOMESTIC WATER SOFTENER

This is shown fitted to the rising-main house service pipe, which feeds the various points direct. The by-pass and stop-valves allow hard water to be delivered to the taps during the time required for the water softener to be regenerated. Where the entire hot- and cold-water supply is taken from supply tanks fed from the softener, there is no interruption of the supply of soft water.

Medical and scientific opinion is overwhelmingly in favour of softened water for drinking, personal hygiene, and domestic use. Softened water is desirable in almost every industry. It effects enormous economies; and commercial processes of dyeing, paper-making, etc., are not affected. The fact that some people are sceptical about using too soft a water is due to their experience or knowledge of the action of the naturally soft waters referred to above, and most certainly does not apply to water softened by the domestic or commercial base exchange softeners.

The Rating of a Water Softener

In rating the output of a softener a hardness of 16° Clark is taken as the standard; thus a softener rated at 1,000 gal. would produce 730 gal. in the Southport area, which is 24°, or 600 gal. in Bedford, which is 30°.

Estimating Consumption of Water and Output of Softener Required

The water consumption per head per day varies from 25 to 40 gal., according to the number of baths taken. It is desirable, where possible,

to provide for weekly regeneration of the softener, which then becomes a regular routine job. Considering a family of six persons, and allowing 30 gal. per head per day as an average consumption, it will be seen that a softener capable of giving an output of 1,260 gal. on the hardness of the district concerned should be suggested. Where the amount for initial outlay is limited, a similar plant of, say, 650 gal. could be installed for bi-weekly regeneration.

Types of Small-capacity Softener

Softeners of these capacities measure approximately 53 in. by 12 in. and 36 in. by 9½ in. respectively, with an additional allowance of 6 in. at the front for the projection of the valves. These models are suitable for fixing in the kitchen, washhouse, or basement, whilst smaller models measuring 33 in. by 9½ in. are suitable for fixing under the draining-board of the kitchen sink. The output of a model this size is 500 gal., and is suitable for a family not exceeding four persons. Regeneration of the foregoing models is by placing salt through the inlet cap at the top, and washing this through the softener to the drain. This process takes about five minutes' personal attention, and twenty minutes to be left running to the drain.

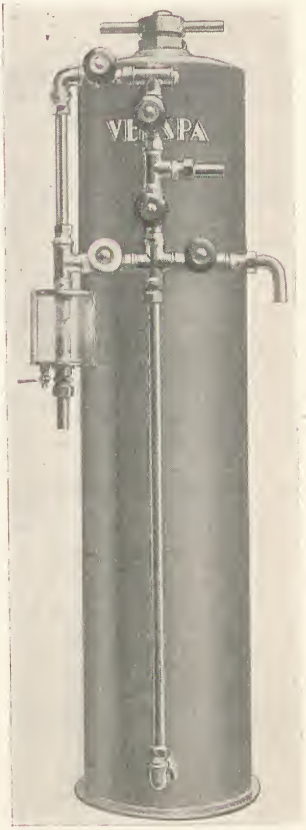


Fig. 2.—DOMESTIC WATER SOFTENER FITTED WITH VISIBLE BACK FLOW AND BRINE CONTROL

The glass cylinder on the outlet to drain enables the user to observe, by the clarity or otherwise of the water passing through it whilst back-flushing, whether or not the softener has been cleared of all foreign matter. ("*Vel-Spa*" *Water Softeners*)

Types of Softener for Larger Capacities

In calculating for larger capacities, it must be noted that the minimum time in which the entire output of the softener should be taken is eight hours. Regeneration of these models is by the siphonic method. Sufficient salt is loaded into a separate tank or cylinder to provide for several regenerations. This unit is then filled with water, and a certain quantity of this is siphoned through the salt into the softener in the form of a saturated brine solution. This brine solution is then washed to the drain, as with the smaller models. The time occupied in personal attention is about ten minutes, with thirty minutes' run to the drain. The usual number of regenerations taken from one loading of salt into the brine cylinder is eight. It is not an economical proposition to install

a multi-regenerator type of plant of greater output than 4,500 gal. at 16° between regenerations, owing to the large size of regenerator cylinder required, and the tendency of the final siphoning of brine solution to be below strength. Furthermore, when the salt consumption per regeneration approaches 56 lb.—which it does at this output, the actual amount being 47 lb.—it is preferable to incorporate the double-regeneration system detailed below.

For Capacities over 4,500 gal.—the Double-regeneration System

In blocks of flats, and for industrial purposes where large quantities of water are consumed, it is an economy to install a softener which incorporates the system known as double regeneration. This provides for an upwards and downwards flow of the same brine solution through the bed previous to opening the wash-to-drain valve, and effects an economy of 40 per cent. in the consumption of salt.

To Provide Uninterrupted Supply of Softened Water at All Times

When the entire hot- and cold-water supply for a residence or flats is taken from supply tanks fed from the softener, there is no interruption of the supply of soft water ; but where the softener is connected to the rising main feeding the various points direct, it is advisable to provide a by-pass which will supply hard water during the time required for regeneration—usually thirty to forty minutes. The method of doing this is described later. Alternatively, two smaller softeners can be coupled to the main, and regenerated in turn from the same brine cylinder. This provides an uninterrupted supply of softened water at all times. In either case, soft water can be drawn uninterruptedly from the hot-water system, but it must be borne in mind that if the system of by-passing hard water during regeneration is adopted, all the soft water drawn from the hot system during this time will be replaced by a corresponding quantity of hard water. Large-type softeners range in output from 5,000 gal. to 20,000 gal. per regeneration. The respective sizes are approximately 60 in. by 20 in. and 90 in. by 30 in., and the brine cylinders 30 in. by 15 in. and 36 in. by 18 in. respectively. An additional 6 in. should be allowed for the projection of the valves at the front. The fixing site for the larger models is usually in the basement, or in an outbuilding specially incorporated in the plan for this purpose.

Storage Space for Salt Required

In this allotment of space provision should be made for the storage of the salt required for regenerating the plant. Five 1-cwt. bags of salt can be stored in a space 52 in. by 14 in. by 22 in. high, preferably standing on wood laths raised 1 in. away from the floor, and spaced about 2 in. apart. Similarly spaced laths can be built up to a suitable height forming shelves, care being taken to avoid the salt coming into contact

with the actual brickwork, and ensuring a free circulation of air.

Position of the Softener

There is no objection to a water softener being housed in the same building as, or in reasonable proximity to, heating apparatus, if this is essential, but if coke is used as a fuel care must be taken that water required for regenerating purposes does not remain any length of time in the brine cylinder. This is best loaded with salt, and filled with the necessary amount of water for immediate siphoning into the softener. When softeners are installed inside a residence, as in the kitchen, larder, or under draining-board, it is desirable to stand the softener on a lead tray built up to a height of about 1 in., to protect the lino or woodwork from the effects of condensation.

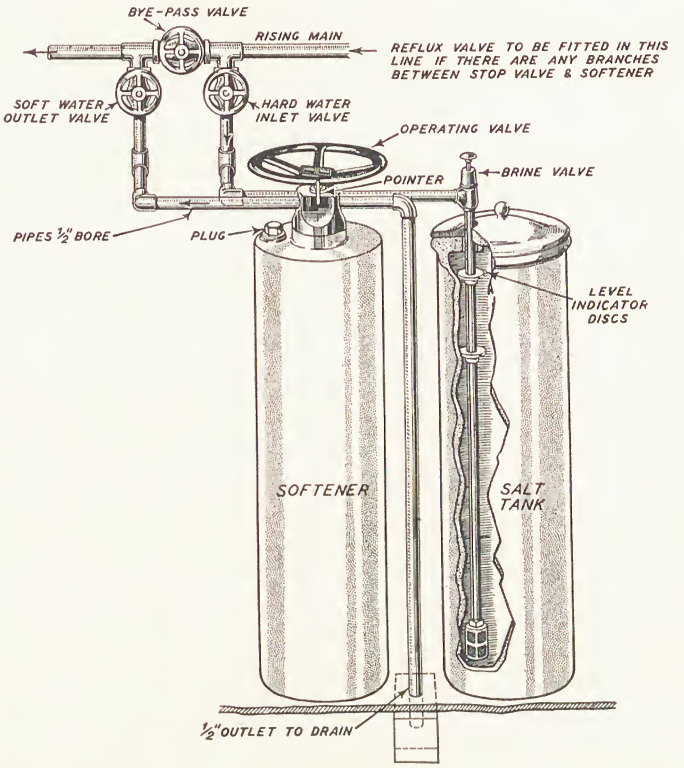


Fig. 3.—TYPE OF SOFTENER FOR LARGER DOMESTIC CAPACITIES, UP TO 4,500 GAL.

In this type of plant, sufficient salt is loaded into a separate cylinder to provide for several regenerations. When the system needs regenerating, the operating valve is turned and automatically supplies brine to the softener.

Dealing with Water for Flushing Purposes

Consideration must be given to the fact that 2½ to 3 gal. goes to each flushing of the water closet, and some owners stipulate the isolation of all lavatories from the softeners. This entails a separate main being run from a point below that which feeds hard water to the softener, and branches taken from this to the various cistern positions. From the health and cleanliness point of view it is better for all water-closets to be

flushed with soft water, the reason being that hard water precipitates a soft fur or scale even when cold. This scale being of an absorbent nature, and forming out of sight and reach at the back of the trap, becomes objectionable and a suspected source of throat troubles.

Provision of Hard Water

A hard-water tap for drinking purposes and for washing of vegetables is sometimes demanded. This can be taken from any position on the hard inlet pipe before it enters the softener, and run to its required position, usually over the kitchen sink. There is no point in stating that hard water is necessary for bone and teeth formation in children. The "lime" contained in hard water is in the form of carbonate and sulphate, whereas the "lime" required for bone and teeth formation is phosphate of lime, i.e. calcium phosphate, which is not present in hard water, but is derived from food—preferably milk, fish, and from sunshine.

Pipe Connections

The valves and connecting unions on softeners up to 750 gal. output are usually $\frac{1}{2}$ in.; connections to the multi-regenerator models are usually $\frac{1}{2}$ in. up to 800-gal. models, $\frac{3}{4}$ in. for the models up to 3,000 gal., and 1 in. for the 4,500-gal. models. The double-regeneration models of 5,000 to 10,000 gal. have $1\frac{1}{4}$-in. valves and connections. Above this, and up to 20,000 gal., the valves and connections are $1\frac{1}{2}$ in., unless specified larger for exceptional rates of flow. The hard-water inlet and soft-water outlet can be specified either right- or left-hand, to suit the fixing position, and the fixing unions can be specified in male or female standard water thread, patent unions for copper pipe, or with lead tails for wiping to lead mains, in bent or straight pattern.

Connections to Drain

A run-off pipe must be taken from the salt-water outlet on the softener to the nearest drain. This pipe can be of copper or lead. Iron pipe should be avoided, for the obvious reason that it becomes affected by the salt water.

Regulations

The requirements of water boards vary considerably, and their rulings should be ascertained. Most reputable makers use J.C.S.W.R. valves as standard, and these are acceptable to all water boards, but they must be stamped by the board in whose district the softener is to be fixed. The manufacturer can arrange for this. In some districts the board stipulates that all softeners must be tested to a specified hydraulic pressure of usually 150 lb. per square inch. Mains pressures vary between 30 and 70 lb. per square inch. Other boards require that a plate be affixed to the softener stating the year of make, serial number, maker's

address, and provision for their own stamp. Where the fixing of a reflux valve is stipulated, this must be fixed on the hard rising main in a vertical position on a point before its entry into the hard inlet of the softener, or to conform with some regulations at the nearest point after the stop-tap at which the main enters the building. The fixer must notify the board of the installation on the appropriate form issued by them for that purpose.

Installing Softeners on Pumped Supplies

The installation of domestic plants for pumped supplies involves one particular difficulty. As a general rule the whole of the requirements for the day, or possibly for two days, are pumped in a very short time ; for example, the pump may have a capacity of delivering 200 or 300 gal. per hour and will be worked only for an hour each day ; in consequence, if the softener is installed on the supply to the tank, it is necessary for the plant to be capable of dealing with the water at the maximum delivery rate of the pump, although for the rest of the day it will be standing idle. Consequently it is very much more economical to install the softener after the supply tank. In cases where this is not possible, the makers should be furnished with full particulars as to the type of pump, size of connections, output per hour, height of storage tank to which supplies are to be pumped through the softener, and the capacity of this tank. The architects should have assurances as to the satisfactory working of the plant, and stipulate that a pressure release valve is installed on the feed pipe between the softener and pump as a safeguard against strain on the pump, or the mounting up of pressure in the softener through clogging of outlet filter with foreign matter. Where the softener is fixed after the supply tank, there should be as much height as can be obtained between the two in order to give as good a pressure as possible for back-flushing the softener. The loss of pressure through a softener is very low, but varies according to the density of the bed used. For low pressures, therefore, the architect should specify a coarse bed of, say, 10/30 grade, i.e. the coarsest grains would remain on a 10-mesh sieve, and the finest on a 30-mesh to 1-in. sieve. Total water pressure available is determined by multiplying the head of water in feet by 0·434, = lb. pressure per square inch.

Installation and Maintenance

After the connections have been made by the fixer the softener should be back-flushed for at least fifteen minutes before being put into use. A spare rubber washer for the salt cap should be left, and fitted if at any time a seepage of water occurs at this point. Clogged filters can be taken out and cleared by disconnecting and removing the valve assembly, and withdrawing these by means of either the slotted-tube end or hexagon nut provided. To replace the bottom filter tube it is

necessary to lay the softener on its side or end. The plant should be well back-flushed after removing bottom filter, to distribute the bed evenly. Complaints as to non-delivery of soft water are usually due to overrunning the plant, and can be remedied by regenerating two or three times in succession before drawing any soft water from the plant. The only other servicing likely to be required is tightening the gland nut on the valves, which may be necessary after six or twelve months' use, or replacing a valve washer, either of which can be done by the plumber in a few minutes.

Various Softeners Described

In order to try to " simplify " the working of a softener numerous makers have at different times introduced a single valve which, when turned to different positions indicated, opens or closes the water circuit necessary for the particular operation to be carried out ; i.e. normal working " hard inlet " and " soft outlet " " on," all others closed. In back-flushing, the " hard inlet " is diverted to bottom of softener, and outlet to drain is opened, all others being closed. For regenerating, normal " hard inlet " and outlet to drain both open, all others closed. One objection to these is that as the rates of flow and working cycles are so unequal there is uneven wear.

Hydraulic and Electrically Time-controlled Softeners

If conditions were constant, automatically controlled softeners might fulfil a definite use ; but as the amount of suspended matter in water varies according to seasons and the position of the building in regard to the water main service, it will be seen that no specified time can be determined for the correct back-flushing of the plant. But for those with a flair for automatics they can be installed, with due regard to this latter point.

Provisions for Regenerating and Testing

In addition to observing as to correct and adequate provision for back-flushing, the architect should satisfy himself as to convenience of regenerating and testing. Many softeners are fitted with an open funnel into which the salt water flows during regeneration ; the possibility of dampness and corrosion being caused by splashing should be watched here. Other types run straight to the drain, with or without the interposing of a test tap. This entails going outside to ascertain that the water is not flowing too fast or too slow. Several models have a totally enclosed glass cylinder on the outlet to drain, fitted with a small testing tap on the lower side. Through this cylinder it is quite simple to observe that the water is running at its correct rate of flow—which is essential for efficient regeneration—and it also enables the user to observe, by the clarity or otherwise of the water passing through it whilst back-

flushing, whether or not the softener has been cleared of all foreign matter.

Fittings and Filters

Internal filters of stoneware sometimes fitted often give trouble by cracking and clogging, and are difficult to remove. Apart from the cylinder, all iron fittings, whether galvanised or not, should be avoided, excepting where first cost is of importance, as with housing schemes. Various softeners are available which incorporate stainless steel filters, and all-chrome-plated-on-gun-metal valves and fittings. Most manufacturers, also, offer a choice of attractive colours for the modern kitchen.

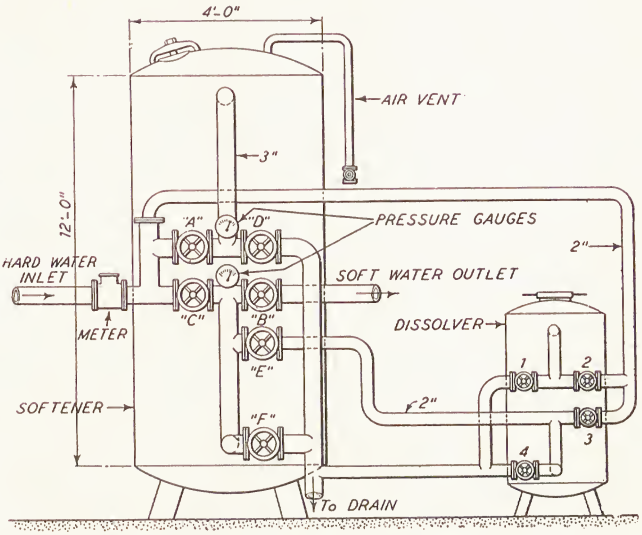


Fig. 4.—Arrangement of 30,000-gal. water softener for block of flats or industrial uses

The method of working is as follows: For softening, open valves A and B. For back-flushing, open valves C and D. To prepare brine, remove cover on dissolver and run off water by opening valve 4 until vessel is approximately half empty. Close valve 4. Place 154 lb. of salt in vessel and replace cover. For regenerating, open valves 2, E, and D, and allow flow to continue until effluent no longer tastes of salt and gives zero hardness on test. Close valves 2, E, and D, and open A and B to resume working. To clean brine dissolver, open valves 1 and 3. ("*Vel-Spa*" *Water Softeners*)

Points of Economy

It should be noted by both architect and builder that the inclusion of a water softener not only eliminates the cost of supplying and erecting a rain-water tank, but enhances the appeal of the residence to the prospective purchaser. A water softener definitely saves tea, soap, soda, etc., and it increases the life and efficiency of the hot-water system. High-efficiency copper back-boilers can be fixed in hard-water districts when a softener is installed.

Other Methods of "Softening"

Several types of "softening blocks" are marketed. These contain principally tri-sodium phosphate, and if placed in the supply tank, "lime" is precipitated, which necessitates frequent cleaning out, or

trouble is likely to occur in the feed outlet. Small rectangular boxes or cylinders containing this substance can be fitted to the incoming main, but they are prohibited by several water-supply companies.

Zinc cylinders containing various substances, and floating glass cylinders containing neon gas and mercury, can be placed in supply cisterns. The former exert some form of electrolytic action, and result in less scale forming in back-boilers, etc. The latter emit short-wave rays which alter the physical state of the salts present and prevent the formation of scale. The water possesses a " softer feel," but responds to no standard test for softness.

Provision of Water during Regeneration

Reference has already been made to the fact that a limited quantity of water can be drawn from the hot-water supply ; but it is preferable, for the slight extra cost involved, to fix the softener in the following manner. Loop from the under side of the existing main stop-tap direct to the " hard inlet " of the softener, and interpose a stop-tap on this pipe. Take a similar loop from the soft outlet of the softener to a position above the main stop-tap, and interpose a further stop-tap on this pipe. By opening the main stop-tap during regeneration, there is a supply of water both for the building and for regenerating the softener ; but care must be taken to turn off the main stop-tap after regeneration. The provision of the two additional stop-taps on the looped-in pipes makes it possible to isolate the softener for repair or removal by turning both of these off, and opening the main stop-tap. Water softeners thus fixed can be very quickly and easily removed in case of repair or alteration ; or if the property of the tenant and required for installation in another residence. The extra cost of this method, including the stop-tap for a $\frac{1}{2}$-in. mains supply, should not exceed 20*s*., including labour, the necessary lead pipe, and joints.

Types of Bed Used

The original beds used in base-exchange softeners were of natural origin, such as Australian Greensand, Sussex earth, and similar rock or quarried beds imported both from the Continent and from the U.S.A. These beds soften only by " surface contact," and being of low efficiency entail the use of large cylinders. They are being superseded by " synthetic " beds. These have over three times the efficiency of the natural beds, and being porous soften by percolation through the entire bed. Their life is equal if not superior to that of the natural bed. There are a number of standard and imported beds, and a few proprietary grades of high efficiency produced to the exclusive specifications of designers and patentees. Such beds are usually guaranteed for a period of from three to five years.

Regenerator Tanks and Cylinders

The use of galvanised iron has been superseded by stoneware and chemical ware, the latter being preferable as not being affected by salt, and less liable to chip and crack. They can be supplied in rectangular or cylindrical form. There are other types of regenerators which incorporate brine filters and operate under pressure. These are made from galvanised steel, with chrome-plated-on-gun-metal valves, and are most economical in use.

USEFUL FACTS ABOUT WATER

The Analysis of Water

The process of analysing water requires considerable laboratory apparatus, a highly sensitive chemical balance, and considerable skill and experience. Notwithstanding this, a great deal can be learned about the quality of a water by observation and a few simple tests. The amount of suspended matter can be observed with sufficient accuracy to indicate the general quality of the water in this respect. The suspended matter in a town's supply would be extremely small or nil, whilst spring water would indicate considerable quantities, particularly during the early months of the year. Canal and river water would indicate considerable quantities of suspended matter, particularly during floods. The nature of this suspended matter, whether in the form of clay, sandy particles, or vegetable matter, can usually be determined fairly accurately without chemical analysis or microscopical examination. If suspended matter is present, it should be filtered out before chemical analysis, using chemical filter paper and a glass funnel. Observation should then be made as to colour and odour. A brownish-coloured water usually indicates the presence of organic matter, as for example surface waters from peaty or moorland districts, which are usually brown in colour, due to solution of humic organic acids from the peat. A greenish cast in the water may be due to algæ or other related living organisms. Care should be observed in the detecting for odour, as obscure throat troubles can be set up from waters containing various effluents. It is possible to obtain from laboratory furnishers and certain chemists various indicators which determine whether a water is acid, neutral, or slightly alkaline. From the foregoing a good idea can be obtained as to the general quality of a water, its corrosiveness, hard or soft scale-forming properties, and its suitability or otherwise for the purpose in mind; but for a detailed analytical report and advice an expert should be consulted.

Testing for Total Hardness

The hardness of water is expressed in degrees Clark—the standard adopted in Great Britain. There are 70,000 grains in 1 gal. and each

grain of dissolved lime or magnesium per gallon is described as imparting one degree of hardness, e.g. 24 grains in 70,000 (1 gal.) is 24° hardness (Clark). The laboratory test for hardness is as follows : 50 c.c. of water are used for the test—an ordinary medicine bottle is suitable. Clark's standard soap solution is then added from a burette in portions of 1 c.c. at a time. The bottle is shaken at intervals, and when a lather is obtained which persists for five minutes the quantity of soap solution required to produce this is noted and the hardness ascertained by reference to the table of quantities. For the domestic or commercial user of a water softener the procedure is much simpler. It is only necessary to know whether the water is soft or hard, and not the degrees of hardness. For this purpose the makers supply a test set consisting of a small glass-stoppered bottle with an indicating line etched at a height showing when it contains 20 c.c. of water. Another bottle contains soap solution of a special strength. Five drops of this are released from the special grooved stopper, and the sample of water shaken. If lather persists for a few minutes the sample is soft, but if a lather is difficult to obtain, or flaky curds result, the sample is hard, and the softener should be regenerated at once.

Alkalinity Test for " Temporary " Hardness

Apparatus required : (*a*) One-fiftieth normal (N/50) standard acid. (*b*) Small bottle of methyl orange. (*c*) One 70-c.c. pipette. (*d*) One 25-c.c. burette. (*e*) One white saucer.

Method.—Measure 70 c.c. of water into the saucer from the pipette. Stir into this two or three drops of methyl orange (exact quantity not essential, but larger quantities make the test more difficult). This will turn the water yellow. Fill the burette with N/50 acid and run some into the water, stirring all the time. After the addition of a certain quantity the colour will change from yellow to pink. Stop the addition of acid and read off the amount added (say 16 c.c.), which will mean 16° of temporary hardness. We have already ascertained the *total* hardness by Clark's soap test previously described, and by deducting the figure indicated by the alkalinity test from that shown by Clark's test we obtain the figure for " permanent " hardness, e.g. :—

Total hardness . .	(say) 24° by Clark's soap test.
Temporary hardness .	(say) 16° by methyl orange test.
Permanent hardness . .	8° by difference.

The salts usually found in waters are as follows :—

Calcium	Sulphate	$CaSO_4$
	Carbonate	$CaCO_3$
	Bicarbonate	$CaH_2(CO_3)_2$

Magnesium	Carbonate	$MgCo_3$
	Chloride	$MgCl_2$
	Nitrate	$Mg(NO_3)_2$
	Bicarbonate	$MgH_2(CO_3)_2$
Silica		SiO_2
Ferric Oxide		Fe_2O_3
Alumina		Al_2O_3
Sodium	Nitrate	$NaNO_3$
	Chloride	$NaCl$
	Sulphate	Na_2SO_4
	Carbonate	Na_2CO_3
	Bicarbonate	$NaHCO_3$
Calcium	Nitrate	$Ca(NO_3)_2$
	Chloride	$CaCl_2$
Magnesium Sulphate		$MgSO_4$

All calcium salts other than calcium bicarbonate are a cause of permanent hardness.

Other salts may assist in the formation of scale and/or corrosion. In waters polluted by industrial workings, i.e. gas plants, etc., ammonium salts are usually present. These are extremely corrosive, dissociating under boiler conditions into free acid and ammonia. Calcium bicarbonate is present when water has passed through limestone or marble geological strata. Calcium chloride is seldom present in waters ; but in the presence of magnesium sulphate it reacts with the latter salt, giving rise to a sulphate scale, with the formation of magnesium chloride. Magnesium chloride is one of the worst impurities to be found in a feed-water. It is also produced by the reaction of a magnesium salt with other chlorides. The conditions referred to here are seldom encountered in districts recommended as suitable for the installation of base exchange softeners, but will serve as a guide to circumstances which may prevail in other areas where the water is not taken from a supply company, but obtained from private sources, such as deep or shallow wells, mine water, canals, or rivers.

" Temporary " and " Permanent " Hardness

The " temporary " hardness of a water refers to those salts which can be precipitated by boiling, and the percentage of this " temporary " hardness is determined in the analysis. Carbonates are held in solution as bicarbonates by carbonic acid. The application of heat drives off carbonic acid, the bicarbonates are thus thrown out of solution as insoluble carbonates and deposited as scale or " fur " in kettles, etc.

" Permanent " hardness refers to those salts which are not precipitated by boiling. They are the sulphates, nitrates, and chlorides held in simple solution, and are not dependent upon carbonic acid for solubility ; consequently they are not precipitated by boiling. They are precipitated by evaporation and form extremely hard scale. They also act as a

"cementing" agent in forming and hardening matter already precipitated into a harder form of scale. The base exchange method of softening converts both the temporary and permanent hardness irrespective of their nature and proportions. Typical examples of proportions are as follows—

Temporary Hardness (in Degrees Clark)	*Permanent Hardness (in Degrees Clark)*	*Total Hardness (in Degrees Clark)*
3·5	14·5	18
22·0	12·0	34
17·5	14·0	31·5
28·4	3·5	31·9
13·5	6·0	19·5

In conclusion, it will be seen that the information contained in this article enables both architect and builder to advocate the installation of water softeners with every assurance of creating desirable property.

HARDNESS IN VARIOUS DISTRICTS

Ashton-under-Lyme	4°
Bath	20°
Bedford	26·9°
Belfast	1·8° and 7·7°
Birkenhead	2·8°
Birmingham	20° and 30°
Bournemouth	14°
Bradford	2·5°
Brighton	14·5°
Bristol	10·5° and 16°
Cambridge	19°
Cork	3·4°
Coventry	9·8 and 26·6°
Dartmouth	13·16°
Derby	5° to 6°
Dover	22°
Dublin	2° and 4·5°
Dundee	2° to 7·2°
Edinburgh	4·3° and 10·2°
Glasgow	0·8° and 3·7°
Gloucester	24·15°
Gt. Grimsby	21·75°
Halifax	3°
Hartlepool	36°
Ipswich	30·66°
Lancaster	2°
Lincoln	9·8°
Liverpool	1·05° and 13·2°
Manchester	2·1°
Metropolitan Water Board, London	16·10° and 20·44°
Oxford	21·8°
Peterborough	37·25°
Portsmouth	15·75°
Reading	15° and 17·1°
Southampton	8·2° and 9·3°
Southport	21°
Stockport	3·4° and 6·3°
Worcester	10°

QUESTIONS AND ANSWERS

How "Hard" is Water after treatment by the "Base Exchange" Method?

It is of zero hardness.

What is the object of using "Soft" Water?

(1) It increases the life and efficiency of the hot-water system by eliminating furring-up, etc.

(2) Saving in tea, soap, soda, etc.

(3) Enables high-efficiency copper back-boilers to be used in hard-water districts.

(4) Improvement in health and hygiene in personal use.

Why do Corrosion and Pitting sometimes occur with naturally "Soft" Waters?

Corrosion and pitting can occur with naturally "soft" waters from peaty moorland districts which contain humic acid, and with waters containing iron salts in any quantity. Frequently rain-water in industrial districts will indicate acidic properties due to absorption of atmospheric gases. These waters have a solvent or corrosive effect upon metals, particularly boilers, and in all cases of doubt or suspected presence of corrosive waters the makers should be consulted.

How is a Water Softener rated for Output?

A hardness of 16° Clark is taken as the standard; thus a softener rated at 1,000 gal. would produce 730 gal. with water at 24° Clark.

How may an uninterrupted supply of Softened Water be provided at all times for Domestic Purposes?

(1) If the entire hot- and cold-water supply is taken from supply tanks fed from the softener.

(2) Two smaller softeners can be coupled to the main if the various points are fed direct by the main.

How do you estimate the Output of Softener required?

Take a water consumption per head per day of from 25 to 40 gal., according to the number of baths taken.

It is desirable to provide for a weekly regeneration of the softener, but, where the amount of money available for initial outlay is limited, regeneration twice a week could be provided for, thus reducing the capacity of the softener by half.

What is the Double-regeneration System?

A softener providing for an upwards and downwards flow of the same brine solution through the bed previous to opening the wash-to-drain valve.

What is the advantage of the Double-regeneration System?

It effects an economy of 40 per cent. in the consumption of salt.

What space is required for the Storage of Salt needed for regenerating large plants?

The space can be allocated on the basis that five 1-cwt. bags of salt can be stored in a space 52 in. by 14 in. by 22 in. high.

How should the Salt be Stored in large quantities?

In bags, preferably standing on wood laths raised 1 in. away from the floor, and spaced about 2 in. apart. Similarly spaced laths can be built up to a suitable height forming shelves, care being taken to avoid the salt coming into contact with the actual brickwork, and ensuring a free circulation of air.

Should Soft Water be used for the Water-closets?

From the health and cleanliness points of view it is desirable for all water-closets to be flushed with soft water, for the reason that it prevents the precipitation of absorbent fur in the traps. Where, however, consideration must be given to the fact that $2\frac{1}{2}$ to 3 gal. goes to each flushing, the water-closet can be isolated from the softener by running a separate main from a point below that which feeds hard water to the softener.

Is Hard Water necessary for Bone and Teeth Formation in children?

The "lime" contained in hard water is useless for this purpose. It is in the form of carbonate and sulphate, whereas the "lime" required for bone and teeth formation is phosphate of lime, i.e. calcium phosphate, which is not present in hard water, but is derived from certain foods.

Why is it more economical to install a Softener after the supply tank on Pumped Supplies?

Because if the softener is installed on the supply to the tank and not after, it is necessary for the plant to be capable of dealing with the water at the maximum rate of delivery of the pump. Consequently, a considerably larger softener is required.

What precaution should be adopted when the Softener is fixed after the Supply Tank?

There should be as much height as is obtainable between the supply tank and the softener, in order to give as good a pressure as possible for back-flushing the softener.

SANITARY FITTINGS AND APPLIANCES

PART II.—SINKS, BATHS, AND LAVATORY BASINS

SINKS are essentially appliances used for the washing and cleansing of household and domestic crockery, glass, and other utensils. Sinks are also used in the laboratory and factory for like purposes.

For general use, well-glazed stoneware sinks are eminently suitable. They vary in size and shape, but the deep sink has to an extent replaced the shallower type for most purposes. A softer material is, however, found more suitable where large quantities of china and glass are required to be washed, such as in pantries attached to large houses and institutions, in order to minimise the risk of chipping and breakage.

In these circumstances it is desirable to provide special sinks for this purpose. The sinks used are either hardwood sinks, made of teak, or constructed of other types of wood and lined with metal.

Modern metal-lined sinks may be of lead, copper, aluminium, or other alloyed metals. Lead-lined sinks have the disadvantage of buckling, caused by the irregular expansion and contraction of lead when in contact with alternate discharges of hot and cold water. Continued buckling will cause the lead to crack and allow the water to penetrate between the casing and the metal. Thus in time the sink will become insanitary.

The Overflow

On account of the liability to stoppage by the congealment of grease and other matters, the overflow to a sink should be readily accessible, and large enough to enable it to be easily cleansed.

The Waste Fittings

Two types of brass sink waste are in general use : the slotted plug and waste, and the beacon-type waste—both of which may be obtained in plain brass, or nickel- or chromium-plated.

The slotted waste is bedded down through the sink and secured underneath by a lead washer and back nut. A brass cap and lining provide the connection to a lead trap or waste by means of a wiped soldered joint.

The Belfast or beacon waste consists of two brass flanges, for the top and bottom of the sink respectively, secured together and tightened

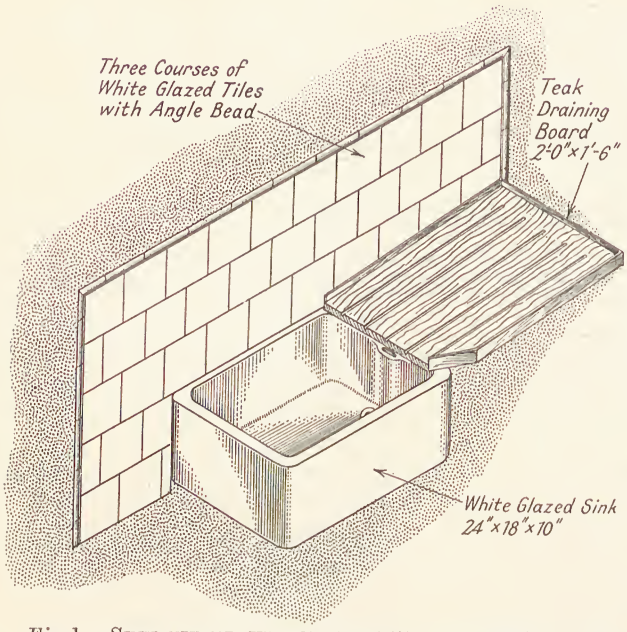


Fig. 1.—SINK FITTED UP FOR ORDINARY HOUSEHOLD USE

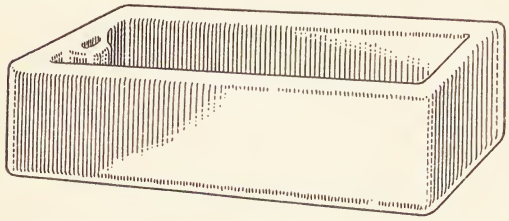


Fig. 2.—ENAMELLED FIRE-CLAY BELFAST-PATTERN SINK

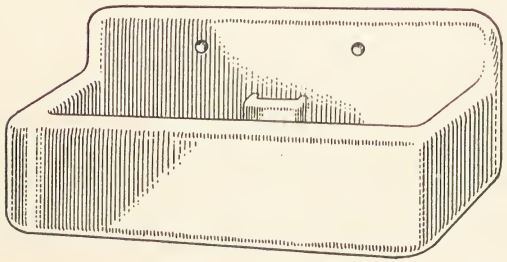


Fig. 3.—BELFAST-PATTERN SINK WITH HIGH BACK, HOLES FOR WATER FITTINGS, AND WITH CENTRAL OVERFLOW

to the sink by means of a long, threaded screw passed down through the centre of each flange. The lead trap or waste is connected to the bottom flange by means of a wiped soldered joint. The flanges are bedded to the sink with a jointing composition such as red and white lead and hemp.

Fixing and Supporting the Sink

Small sinks for household and other uses are now usually supported on cast-iron cantilever brackets built into the wall. This method of fixing and supporting permits the whole sink surround to be accessible for cleansing.

Larger sinks, however, are sometimes supported on white stoneware pedestals screwed or bedded to the floor, or on piers of white-glazed bricks, or piers of ordinary bricks rendered in cement and sand.

The brackets should be built into the wall and the sink placed in position before any rendering or tiling of the back wall is carried out. This will enable the subsequent rendering or tiling to be carried down on to the back edge of the sink, so that splashings are conducted into the sink and not down the back of it.

BATHS

Materials and Types

It is recognised that the provision of a bath or baths in all types of property, and for all classes of people, is necessary and essential to general cleanliness and health.

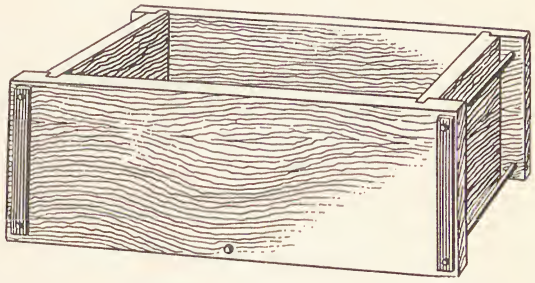


Fig. 4.—HARDWOOD SINK OF TEAK

The standard material for modern baths can be said to be cast iron, vitreous or porcelain enamelled. Cast-iron baths are made in a variety of shapes for all purposes, with roll edge and painted exterior, or with a square top so that marble, imitation marble, porcelain-enamelled, or other types of panel can be fitted to the sides and ends, depending upon the position of the bath.

Cast-iron baths may also be obtained cast in one piece with side skirting, for fixing centrally or in side positions in a bathroom. Roll-edge baths are made with either parallel or taper sides to fit the position for which either type is best suited.

Porcelain-enamelled fire-clay or

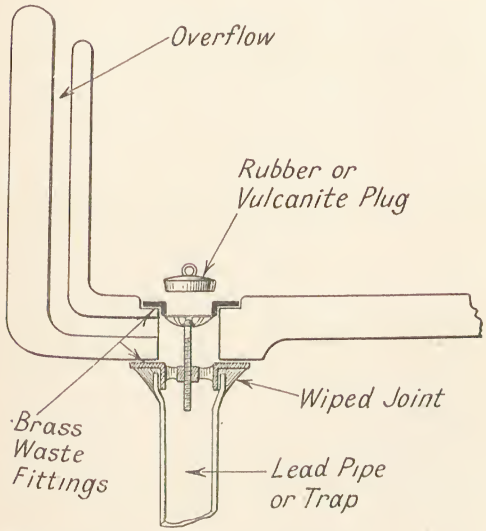


Fig. 5.—PART-SECTION OF SINK, SHOWING WASTE AND OVERFLOW, WITH BEACON WASTE SHOWN WIPED TO LEAD TRAP

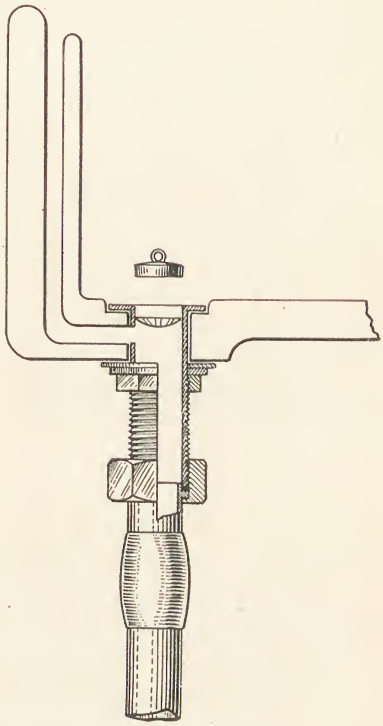


Fig. 6.—SECTION OF UNION WASTE WITH SLOTTED OVERFLOW

stoneware baths are made for perhaps the most exclusive positions. They are glazed inside and outside, and are ideal from the sanitary standpoint. These baths have the disadvantage of being heavy, and from this point of view require to fit in with the construction of the building.

Fire-clay baths are usually moulded in one piece with the sides enclosed, so that the bath can be fixed in a central position in the bathroom. They may also be obtained enclosed on one, two, or three sides, for side-wall positions.

The size and shape of a bath depends upon the position in which it is to be fixed. The standard inside lengths of ordinary parallel or taper baths vary from 4 ft. to 6 ft. (rising at intervals of 6 in.) with the widths varying accordingly.

Sitting baths, or baths formed in the shape of a chair, are made to fit into narrow corners and other spaces where economy in room is needed.

Portable baths are made for hospitals and like institutions. Enamelled copper is a suitable material for this purpose, and the baths are sometimes provided with rubber-tyred wheels. Provision is made in the corridors for filling and emptying.

Special baths that revolve round their waste outlets are sometimes provided in this type of institution, to give facility for cleansing the floor and surround of the bath, and also that an attendant can get on either side of the bath.

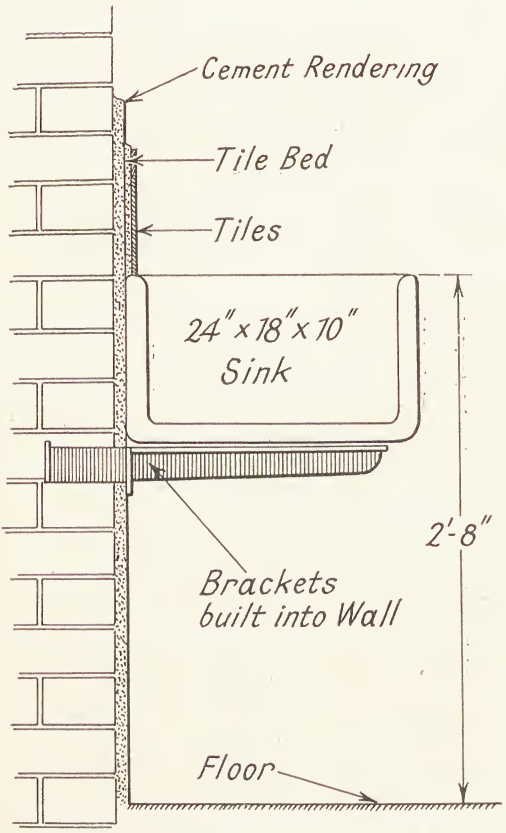


Fig. 7.—SECTION OF SINK ON BRACKETS

Position and Fixing of the Bath

The general tendency is to fix a bath alongside a convenient wall of the bathroom. Where the bath is so fixed, provision should be made for cleaning the surround at the back of the bath. Provision should be made for this when deciding the distance from the wall the bath is to stand. The minimum distance is the space that will permit of the back of the bath to be cleansed.

Square-top baths, with front or front and end panels, or one-piece skirting baths, are invariably fixed close to the wall, so that the wall tiling or rendering is brought down on to the top of the bath edge. These baths are as a rule provided with an anti-splash rim to guide the wall water into the bath.

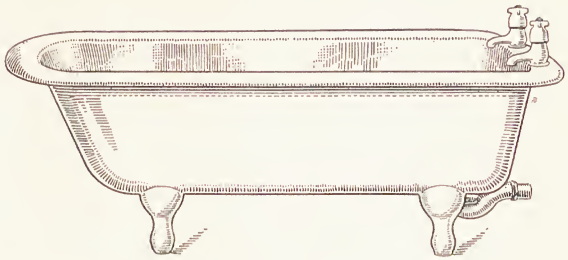


Fig. 8.—ROLL-EDGE PORCELAIN-ENAMELLED CAST-IRON BATH

Sufficient space should be allowed at the head of the bath to give ample access to the plumbing work.

Bath panels are usually fixed by screwing on to a wooden frame built under the edge of the bath. Where side panels are fitted the corners should have prepared edges, or be provided with an angle covering strip.

Island pattern one-piece cast-iron or stoneware baths are fixed centrally in the bathroom, with waste and water control fittings on a side wall. In these cases precautions should be taken to see that the plumbing work, to which it might be necessary to have access, is accessible.

The Waste and Overflow

Modern bath-waste fittings consist of a brass waste and plug, plated or enamelled as the position warrants, and trap. The waste is secured to the bath by a brass back nut and lead washer, with the necessary jointing material to render it watertight.

The waste plug may be of the chain and plug type with rubber or composition plug, or it may be of the lift-up variety. In the latter case the plug is lifted by means of an exposed metal rod.

The older type of enclosed combined overflow and waste may be looked upon with suspicion, owing to its inaccessibility and foulness.

Most water authorities insist upon the bath overflow being turned out through the external wall as a warning pipe, in order that waste of water may be observed. In so doing a current of cold air is permitted to pass through into the bath, which in cold weather is unpleasant. To overcome this a copper flap may be

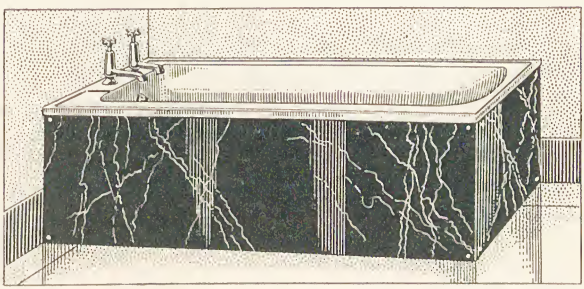


Fig. 9.—SQUARE-TOP BATH WITH FRONT AND END PANELS

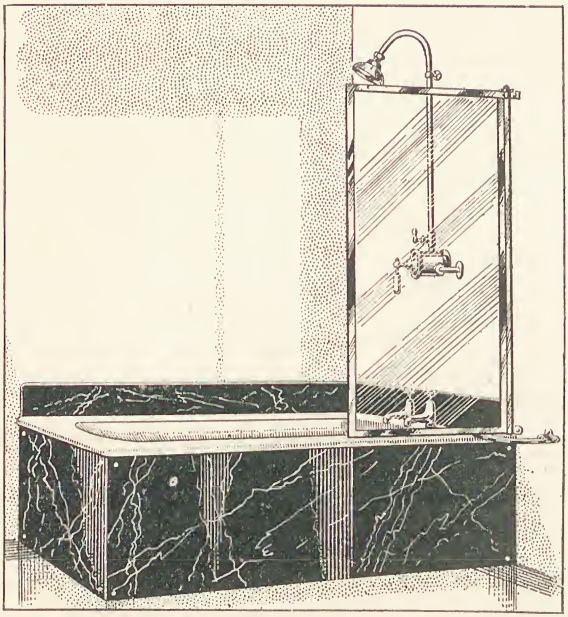


Fig. 10.—COMBINATION BATH AND SHOWER

fixed on the outer end.

The size of a waste pipe from a single bath is mainly regulated by the size of the outlet. The minimum diameter, and the diameter that is suitable to most baths, is $1\frac{1}{2}$ in.

Bath Valves

The type of hot- and cold-water fittings or valves to use with a bath depends again upon the type, quality, and position of the bath. In all cases, whatever type of valve is used, the most satisfactory position to discharge water into a bath is at a point above the overflow level. From this position water may be supplied to the bath through separate valves of either the globe or pillar variety, or through a combined valve.

Globe valves are fixed in the vertical end of the bath, and secured by screwing on to the flanged thread of a bent union. The union is used for the connection of a lead pipe for the hot- or cold-water supply. Pillar valves are fitted on the top of the roll edge, and secured by a washer and back nut. A straight union provides the lead connection to this valve.

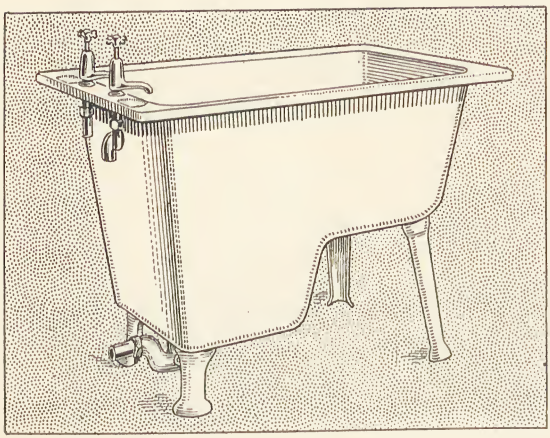


Fig. 11.—CHAIR- OR STEP-TYPE BATH

Combined hot- and cold-water bath valves with a single outlet may be of the pillar type, to be fixed on to the top edge of the bath, or of the horizontal wall type, to be fixed on to a side or end

wall with the nozzle discharging into the bath. The hot and cold water may be controlled by separate valves, or by a mixing valve, so that cold, tepid, or hot water is drawn. The water can be drawn only in this order, to prevent scalding. This arrangement is admirable where a flexible or fixed shower spray is fitted. Anti-scald valves, as these valves are termed, can be provided with loose key for asylum and institutional use.

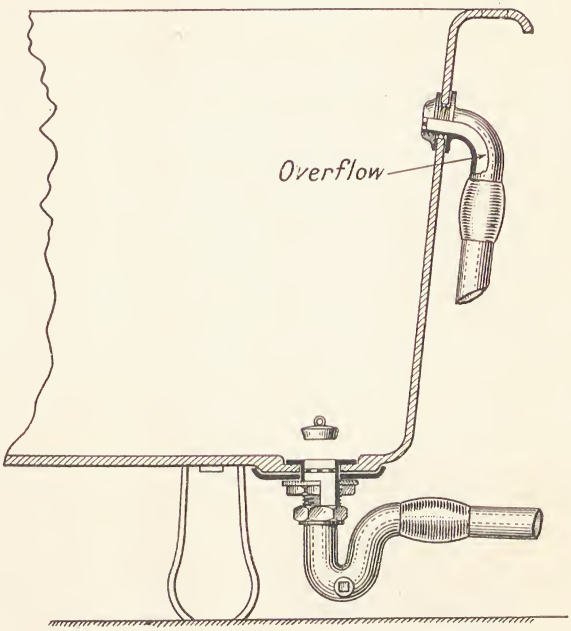


Fig. 12.—SECTION OF END OF BATH, SHOWING OVERFLOW AND WASTE WITH TRAP

Shower Baths

Shower baths for domestic use are arranged by providing either a flexible or a fixed spray to the bath. In the case of a flexible spray, the apparatus consists of a flexible tube attached to the mixing or anti-scald valve, so that it can be held and sprayed as the user desires.

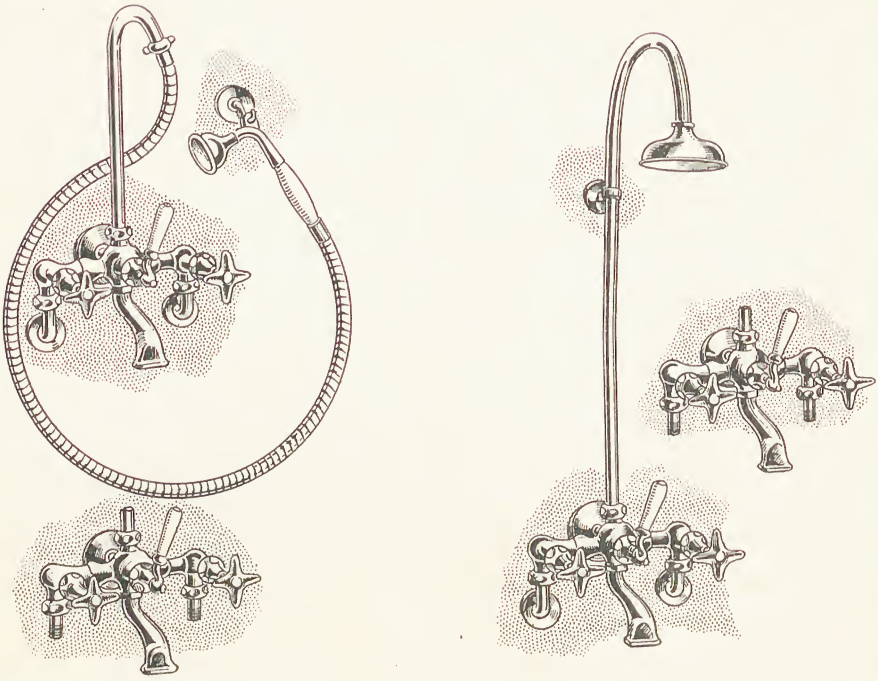
Fixed shower sprays consist of the same type of valve, with plated supply pipes to the spray fixed above the bath. In some cases a curtain is fixed, so that it can be drawn round the user to prevent splashing, and in other more costly installations a plate-glass screen is provided. The screen may be fixed to the bath itself, or it may be hinged to the wall, so that it is independent of the bath.

Shower baths for institutional or sports or other uses are devised in various manners. In all cases either one or a number of sprays is provided, and separated or not, as the case may be, by partitions. Each individual shower may be provided with a glazed stoneware or white-enamelled receiver built into the floor, and provided with outlet and grating, or the shower may discharge on to the floor of the compartment and be conducted, by means of a channel, to a gully trap.

LAVATORY BASINS

Materials and Types

White or coloured glazed earthenware or enamelled fire-clay lavatory basins may be obtained in a number of shapes and



Flexible shower Fixed shower

Fig. 13.—COMBINATION BATH SUPPLY AND SHOWER APPARATUS

qualities, to befit the purpose and position for which they are required.

The basin may be constructed to fit on to brackets screwed or fixed to the wall, or be of the pedestal type, so designed to fit and be fixed on to a floor pedestal of the same material. The basin may be supplied with a marble top, and be supported by plated metal or polished wood legs, or by a polished wood cabinet. The shape of a basin may be rectangular, angular, oval, or semicircular, according to requirements.

Ranges of enamelled fire-clay basins, in any number as required, for use in schools, institutions, or factories, etc., are constructed with overlapping joints, to be fixed upon cantilever brackets built into the wall, or to be supported by cast-iron standards for central positions. Trough lavatories, in the shape of long, rectangular troughs, are often provided in like institutions to those mentioned. Hot and cold valves are provided over the trough, at intervals that would give one person sufficient room to wash.

Enamelled cast-iron lavatory basins may be obtained, and are often used in factories and other places where they are likely to be subjected to rough usage. The fracture and chipping of the enamel, and the conse-

quent rusting and objectionableness, are a disadvantage of cast-iron basins, and enamelled fire-clay is to be preferred.

Special lavatory basins are designed for use in trade establishments, such as hairdressers', and also for hospitals. The basins for use in operating-theatres and post-mortem rooms require special consideration. They should be so designed that all parts of the basin and surround are accessible for cleansing.

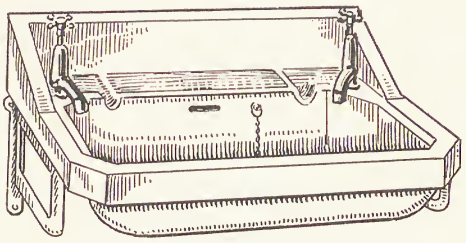


Fig. 14.—LAVATORY BASIN FIXED ON TOWEL-RAIL BRACKETS

The Waste Fitting

For general use the slotted waste with rubber or composition plug is very suitable. The waste is bedded through the bottom of the basin and secured by a back nut and lead washer. The plug and chain are fixed to the basin in a convenient place by means of a stay and nut.

In some cases a metallic plug is used to retain the water in the basin, and is designed to be lifted or lowered by a system of levers. This type is termed a pop-up waste, and may be operated by hand, or, in the case of a basin fitted in an operating-theatre of a hospital, may be worked by the knee or foot, in order that the user's hands may not come in contact with the fitting.

The waste may be supplied with a brass cap and lining for connection to a lead trap or pipe by means of a wiped soldered joint, or one of the several types of brass traps may be used and joined to the waste by means of a screwed cap.

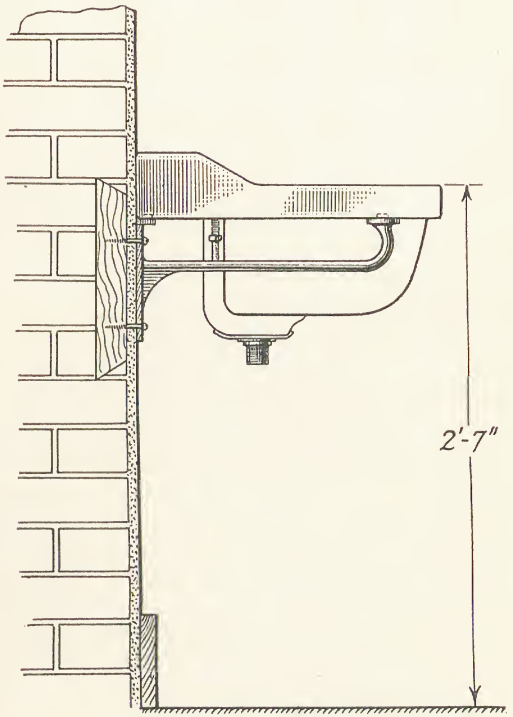


Fig. 15.—LAVATORY BASIN

Section showing towel-rail brackets screwed to blocks built into wall.

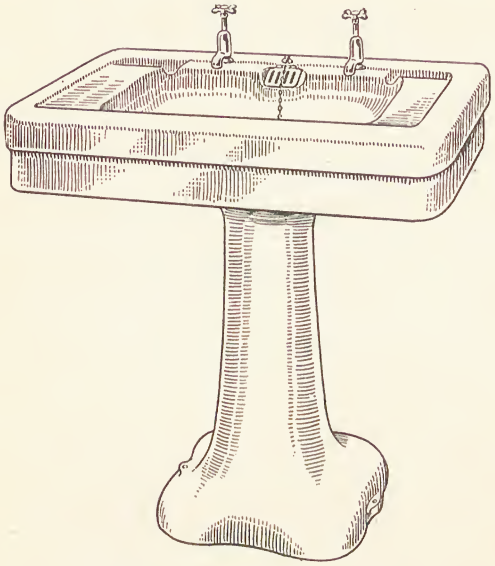


Fig. 16.—PEDESTAL LAVATORY BASIN

The Overflow

As its name implies, the waste fitting is slotted in such a position to enable the overflow of the basin to discharge into the waste. Probably the chief point of construction requiring consideration in connection with a lavatory basin is the arrangement of the overflow. Although many modern basins are constructed so that the overflowing water discharges into the overflow through slotted holes in the back of the basin, this is not considered to be the most hygienic form, as it is usually inaccessible for cleansing.

Accessible overflows, such as those of the weir type, are desirable, because soapy and other matters washing down them from the top of the water are liable to cling to the sides. If the basin is not used for a time these matters will become friable and give off an offensive odour. For this reason the open top overflow is to be preferred because it is accessible.

An exposed standing waste and overflow is sometimes fitted to lavatory basins. This type of combined waste and overflow consists of a short metallic or porcelain tube, so fixed as to enable it to be raised or lowered, and to be easily removable for cleansing purposes. Concealed standing wastes should not be used.

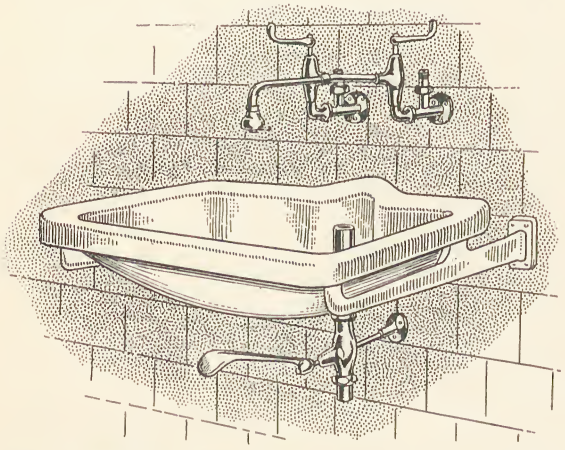


Fig. 17.—HOSPITAL LAVATORY BASIN WITH SURGEON'S KNEE-ACTION WASTE AND ELBOW-ACTION COMBINATION HOT AND COLD FITTING

Lavatory Basin Valves

Independent pillar valves are preferred, and are as a rule used for the modern lavatory basin.

SANITARY SURVEYING

PART VI.—MAKING YOUR REPORT TO THE CLIENT

HAVING previously dealt with the details of sanitary surveying, it is now necessary to summarise the result of the survey in the form of a report to the client.

There are several methods which can be adopted, and the one selected will be governed by the circumstances which called for the survey. It may only be necessary to report on the result of one's inspection, i.e. the condition of the drains, the soundness of soil and waste pipes, the general condition of the sanitary fitments, the water supply, dampness, etc., to a client who is desirous of acquiring the property only if it is in a sound condition ; and it is for the client to decide whether he will take the property on the strength of the report.

What the Report Should Contain

If defects are found, and the client is anxious to obtain the house, very often the present owner is communicated with, with the object of rectifying the defects, or making an allowance in the purchase price by way of compensation. It may be that the property has already been acquired by private treaty, without a survey (which is ill advised), or by auction ; and it is under the latter condition that the report in this case is made, at the same time advising the client as to what is considered necessary to render the property in a sound condition from a sanitary point of view. It is from such a report that, invariably, a specification of the work to be carried out is formulated.

It will be necessary, therefore, for the purpose of this report to assume numerous defects, so as to enlighten the reader not only as to the possibility of their existence, but also as to the work which is necessary to be carried out to render the property fit for occupation.

The property taken for the purpose of the survey is a town house, brick built, with slated roof, and one of a number forming a terrace, with basement rooms, and four floors above ; its age is between eighty and ninety years.

Two methods may be adopted in drawing up the report of the survey. The first is to enumerate the results of the survey, underlining the portions which are unsatisfactory, and then to prepare a complete list of recommendations. The second method is to enumerate the results and follow each section with the recommendations. The second method has been adopted in this case.

The report should be accompanied by a covering letter briefly describing the result of the survey.

DETAILED REPORT

Re No. 14 AUCTION TERRACE

The following conditions were found to exist at the above premises on 12th January, 1937 :—

Drainage

The main drain, which is of iron construction, passes beneath the premises. A water test was applied to this drain, between the front and back manholes, and it was found satisfactory. All the branch drains are of stoneware, and failed to stand a water test.

The brickwork to both manholes is in a good condition, and appears to be of fairly recent construction, but is not cement rendered. The front manhole cover is cracked.

Recommendation.—Renew all existing branch drains, and provide suitable gullies with vertical back or side inlets to receive waste and rain-water pipes. Provide a grease-trap gully for the scullery sink.

Manholes.—Render the sides of both manholes with Portland cement and sand. Renew front manhole cover. The whole system should be retested, including manholes, and made watertight, before sealing manhole covers.

Soil and Waste Pipes

These were found to be of light iron construction, and the soil pipe proved defective on submission to a smoke test. The waste pipes from fittings discharge into hopper heads fixed in the waste-pipe stack.

Recommendation.—Renew the existing stacks of pipes and provide proper junctions with access doors, for the reception of the branch waste pipes, all to be of the weight required by the local by-laws.

Rain-water Pipes

These were found to be generally defective, and permitting, in some cases, water to soak into the wall, causing damp patches to appear on both front and back bedroom walls on the second floor.

Recommendation.—Renewal of all the rain-water pipes, with those having cast-on ears to keep the pipes clear of the walls.

Fresh-air Inlet to Drain

The mica valve was found to be defective, and should be renewed.

SANITARY FITMENTS

Basement

Basement Kitchen

The York stone sink is much worn and fractured, and does not allow the water to drain away completely. The waste pipe, which is of lead, is trapped but in a badly damaged condition.

Recommendation.—Provide, on cantilever brackets, one glazed stoneware sink, and one teak vegetable-washing sink, with properly trapped waste pipes to discharge under a gully grating.

Scullery Sink

This is similar in all respects to the kitchen sink.

Recommendation.—Provide a glazed stoneware sink, fixed on cantilever brackets, and fitted with a properly trapped waste pipe to discharge into the grease gully outside.

Butler's Pantry

The sink is of wood with lead lining, and is defective.

Recommendation.—Remove the existing sink and waste pipe and install a stainless-steel sink, together with a draining-board, and fit a properly trapped waste pipe to discharge into gully outside.

Basement Closet

This closet is a long hopper (obsolete) type ; and is supplied with water from a galvanised sheet-iron flushing cistern ; both fitments are defective. The closet is enclosed in a wood casing, while the fixed window is very small, and the apartment has no permanent ventilation.

Recommendation.—Remove wood casing and closet, render the surrounding wall with Portland cement and sand, and finish with Keene's cement. Enlarge the window to at least 2 sq. ft., with one half to open, and provide permanent ventilation in the form of a ventilating brick to the open air.

Renew closet with a glazed cane-and-white-stoneware pedestal closet with lift-up seat, together with a flushing cistern in accordance with the requirements of the local water company.

Hall Floor

Cloak Room

This closet is a wash-out (obsolete) type, in a foul condition, and enclosed in a wood casing ; the angle lavatory basin is badly cracked.

Recommendation.—Remove wood casing and closet, install a " low-down suite " consisting of a white-glazed porcelain pedestal closet with polished hardwood seat, and flushing cistern. Install new lavatory basin, having a weir overflow and properly trapped waste pipe connected to new main waste pipe.

Second Floor

Bathroom

The bath is of painted cast iron, with a secret standard waste and overflow, and enclosed in a wood casing, with a lead floor tray, all in a much worn and insanitary condition.

The " tip-up " lavatory basin, together with its marble top, is defective, and has a wood casing surround. The waste pipes discharge into a hopper head which is in a foul condition.

Recommendation.—Remove existing bath and lavatory basin, together with the wood casings, and install a porcelain-enamelled parallel cast-iron bath with hand shower fittings, and marble panel surround.

Install a porcelain pedestal lavatory basin, having a weir overflow, and provide properly trapped waste pipes to discharge into new main waste pipe.

Water-closet Apartment.

This fitting is an old-pattern valve closet enclosed in a wood casing, and the whole apparatus is in a defective condition. The window in this apartment is a very small one, and there is no permanent ventilation to the external air.

Recommendation.—Remove existing closet and casing, and install a similar closet to that suggested for the hall floor. Remove existing window, and replace with one having at least 2 sq. ft. of obscure glass, half of which is to open, and provide an air brick above the window as a means of permanent ventilation to the external air.

Bedrooms.

There are no lavatory basins in the bedrooms on this floor, or on the third floor.

Recommendation.—A porcelain pedestal, or flat-back lavatory basin with weir overflow, and with a chromium-plated stand, to be installed in each of the bedrooms.

Third Floor

There is no bathroom, closet, or slop sink on this bedroom floor.

Recommendation.—That the small bedroom immediately above the bathroom and w.c. on second floor be converted for use as a bathroom and w.c. apartment, and fitted out in a similar manner to that described for the second floor. That the large cupboard on the landing be converted to form a housemaid's closet, and fitted with a white-glazed stoneware sink with hot- and cold-water supplies and properly trapped waste pipe. Light and ventilation to be provided by means of a louvred lantern light fitted in the roof.

Hot-water Supply

This is constructed on the tank principle. The hot storage tank shows signs of rusting through. The source of heat is provided by an arched boiler behind the kitchen fire. Upon testing, the system proved most unsatisfactory, and gave indications that furring up of the pipes had occurred.

Recommendation.—Remove the hot-water system entirely, and install a cylinder system of supply, in conjunction with an independent boiler ; provide a secondary circulation from the cylinder, with adequate-size pipes, to permit of abundant supplies of hot water to all lavatory basins, baths, and sinks.

Cold-water Supply

A large, shallow, zinc-lined water tank exists in the roof space, and has a defective cover.

The water service pipes in the roof space are uncovered, with evidence of frequent repair.

Recommendation.—Remove existing tank and provide a 200-gal. galvanised-iron tank, fitted with a dustproof cover and encased with a wood surround, including the top, with a 4-in. space packed with silicate cotton.

Remove existing water pipes, and provide new of adequate size, for all purposes. Either encase all water pipes in roof space with hair felt, bound with copper wire, or box in, and pack space with silicate cotton.

Provide for a main water supply to bedroom lavatory basins, housemaid's sink, pantry sink, and kitchen and scullery sinks. Adequate stop-cocks should be installed at suitable positions to control supplies.

Basement Walls and Floors

There appear to be no damp-proof courses in any of the basement walls, with the result that dampness is in evidence up to a height of approximately 3 ft., which not only gives them a dilapidated appearance, but renders the rooms unfit for occupation. The cupboards on this floor, due to the dampness, are unfit for the storage of food or other dry goods.

The floors are weak and worn, with much evidence of dry rot, while the space between the floor and the ground is unventilated and devoid of site concrete.

Recommendation

Walls.—Remove one course of brickwork, 3 in. below floorboard level in 2-ft. sections, and install a damp-proof course of two courses of slates with broken joints, and set in Portland cement compo, making good the brick course with 2-in. hard bricks set in compo.

Floors.—Remove all floorboards, joists, and sleeper walls.

Install a 6-in. bed of Portland cement concrete over the whole of the floor site, which must be shovel beaten to a fluid face.

Construct sleeper walls in $4\frac{1}{2}$-in. brickwork, omitting occasional bricks for through-ventilation, and install a bitumastic damp-proof course on top of sleeper walls for sleeper plate to rest on.

Install three ventilating bricks in external wall—in front area, and a similar number in external wall at rear of house, so as to ensure through-ventilation of the space beneath floor. Renew the whole of the sleeper wall plates, joists, and floorboards with sound, well-seasoned timber, and treat all plates, floor joists, and under side of the floorboards and skirtings with " Cresote " as a deterrent against dry rot.

Hack off plaster work of all walls to a height of 4 ft., and render with Portland cement compo and sand, making a finished face of Keene's cement.

Roof

The roof is slated, with a lead main gutter, lead chimney gutters, and lead flashings. The main gutter is defective, and there is evidence of frequent repair. The slates generally are in good repair, with the exception of a few which are cracked.

Recommendation.—The main gutter to be taken out and a new 8-lb. sheet-lead gutter installed. The remainder of the lead work should be overhauled, and repaired where necessary, and all cracked slates replaced with sound ones.

Dusthole

This is a brick-built recess with a wooden door. It contains too much filth, and the door is defective.

Recommendation.—That the existing dusthole be cleared away, and two galvanised sanitary dustbins provided.

(*Signed*) A. S., *Surveyor.*

Covering Letter Describing Briefly Result of Survey

1 ADAM COURT,
WESTMINSTER, W.C.
22 *January*, 1937.

DEAR SIR,

Re 14 Auction Terrace

In accordance with your instruction, the above property was surveyed on the 12th inst., and I have much pleasure in submitting a report on its sanitary condition, together with my recommendations to render the house safe for occupation.

You will note that the existing sanitary fitments and waste pipes are obsolete in character, and generally defective, while the drainage work is not entirely unsatisfactory, as the main iron drain, which is sound, appears to have been installed within recent years. There is marked dampness in the basement walls, and the basement floor calls for renewal. The hot-water apparatus requires replacing with a more efficient system. The lead gutter on the main roof should be renewed.

The brick structure is in a very good condition and shows no sign of settlement, while the woodwork generally is in a good condition, and will justify the expenditure of installing new sanitary arrangements throughout, with the exception of the main drain.

I am, dear Sir,
Yours faithfully,
A. S., *Surveyor.*

E. V. Wiseman, Esq.,
10 North Street,
Chelsea, S.W.

ELECTRICAL WARMING APPLIANCES AND INSTALLATIONS

PART II.—INDIRECT ELECTRIC HEATING

OCCASIONS frequently occur where it is necessary to convert an existing hot-water central-heating system to work with electric heat. This can be accomplished by substituting for the solid-fuel boiler a circulator, which is a cylinder fitted with a suitable number of immersion heaters. This is a method often employed in conjunction with slot-meter fires in hotels. A circulator is used to heat hot-water radiators fitted in public rooms. A combined heating system such as this is generally more expensive to operate, has no advantage over the direct, automatically controlled method, but the use of a circulator in place of a solid-fuel boiler makes available for other purposes what would normally be required for a boiler room, as circulators can be fitted with wall brackets if required, but no upheaval of normal routine is caused by re-wiring the building for direct electric heaters.

The load required by circulators is of course proportional to the pipe and radiator surface in the system, and can be found from the Table on page 298.

Automatic Control of Indirect Systems

Automatic control of these systems is by temperature control of either air or water or both. One or more thermostats fitted in a room may be connected to cut off sections of the circulator load, or alternatively a thermostat can open or close an electrically operated valve in the flow pipe to the radiators. In either case such controls, when judged from the view-point of an occupant of a room, are sluggish, and an even temperature is difficult to obtain.

Direct Electric Heaters with Heat Storage

In many districts special low rates for electricity are available provided heating plant is switched off for a few hours. This type of tariff is described as an off-peak tariff, and the peak period—the time during which heaters must be switched off—varies from 2 to 12 hours' duration. In most districts the peak period does not commence until after 4.30 p.m. When electric heaters supplied under an off-peak tariff are installed in, say, offices, which are occupied till about six o'clock, some means of

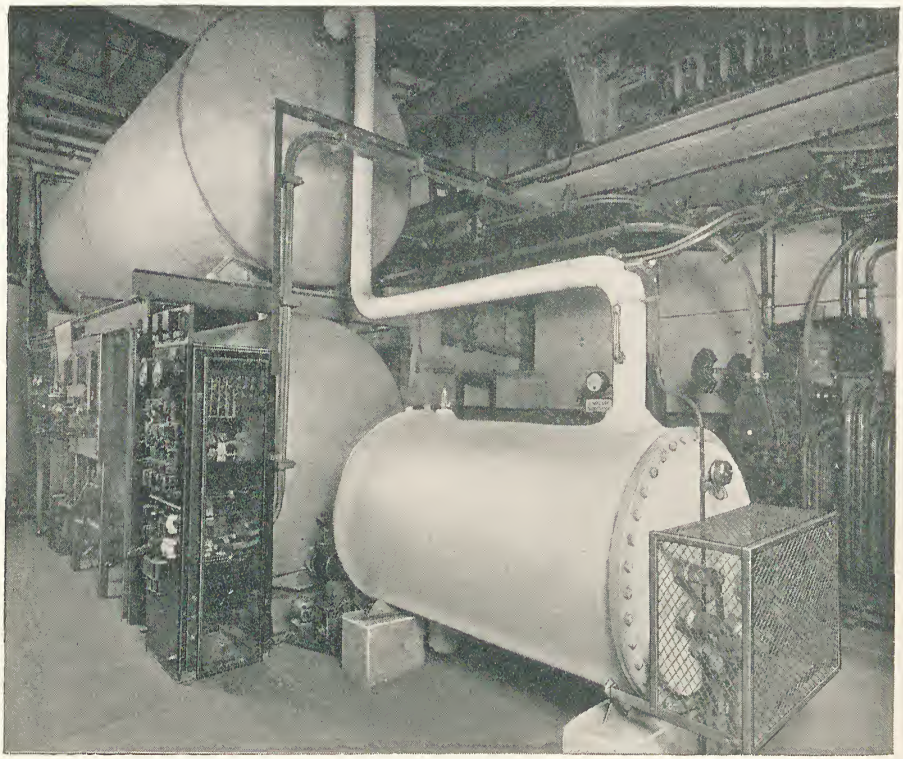


Fig. 1.—THERMAL STORAGE PLANT

This serves the central-heating installation (by hot-water radiators) and the air conditioning plant in two London West End theatres. The photograph shows a 400 kW., 400-volt electrode water heater on the right, and two storage cylinders and automatic control panel on the left. (*The General Electric Co. Ltd.*)

storing heat for upwards of 2 hours must be used. For solidly built and well-heated buildings, the temperature drop in 2 hours may not be sufficient to cause inconvenience, but in others the heating plant must be capable of carrying over the period.

There are at the moment only two types of plant capable of doing this. The first of these is a heater built of soapstone, which becomes heated and liberates its heat after the element is switched off. This appliance can be used where short peak periods exist.

The second type of plant is known as thermal storage plant, and can be designed for any size building and for any off-peak period.

Thermal Storage Plant

In this type of equipment the heat-storage means is water. Large volumes of water are heated to a high temperature, the current supply

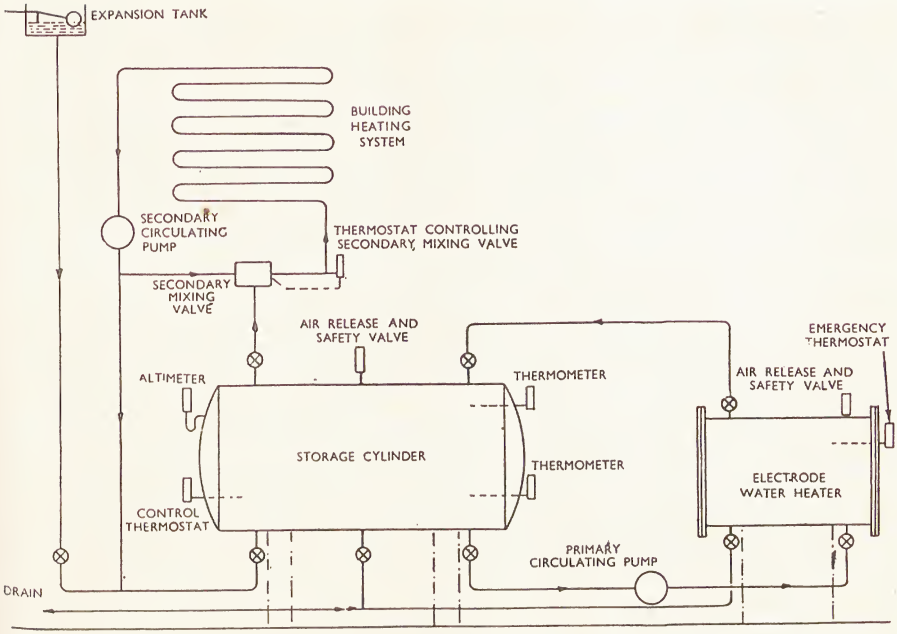


Fig. 2.—General arrangement of an electrode thermal storage plant

Note that it consists essentially of a water heater connected to a storage cylinder. Hot-water circulation between heater and storage cylinder and the circulation for warming the building are induced by motor-driven pumps. (*General Electric Co. Ltd.*)

cut off, and the heat liberated during cooling is used for warming purposes. This equipment is best suited to big buildings, because higher storage temperatures can be used. To appreciate this point a more detailed knowledge of the design of the plant is required.

Electric energy from high- or low-voltage mains, taken during the night hours, is used to heat water stored in heavily insulated cylinders. The heating means is either an electrode boiler working direct upon high- or low-tension supplies, in which the water is used as the resistance medium, or immersion heaters. Immersion-heater installations are limited to loads of about 100 kW. or 340,000 B.Th.U. per hour.

Layout of Plant

A diagram showing the layout of the plant is given in Fig. 2. It can be seen that there are two sections—primary and secondary. The primary side is at work only when energy is being consumed : the secondary side is responsible for delivering heat to the building.

The diagram shows only the heating side of the installation, but the electrical equipment provided is generally such that the plant is entirely automatic as regards temperature control and time factors.

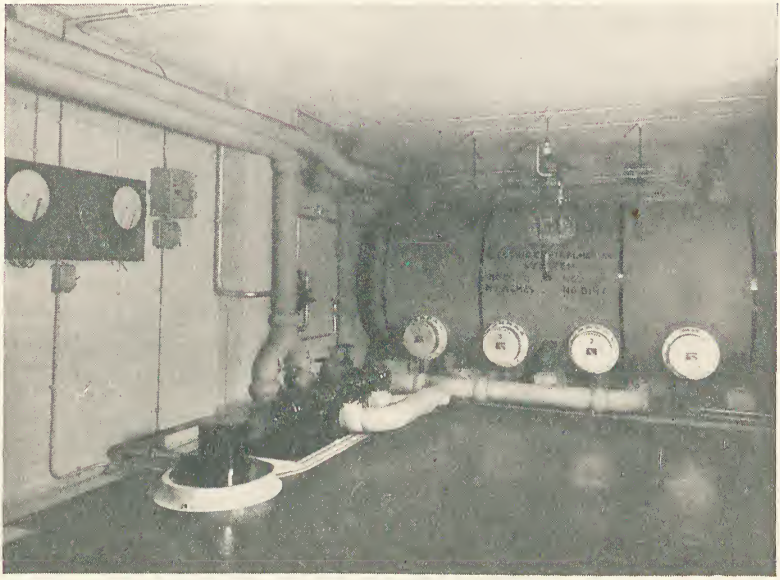


Fig. 3.—THERMAL STORAGE CYLINDER FITTED WITH FOUR 30 KW. IMMERSION-HEATER BANKS

Installed in West Ham Corporation offices. Compare with electrode heater installation, Fig. 1, where the heater is separate from storage cylinder. (*A. Reyrolle and Co. Ltd.*)

Calculation of Storage

In storing a fixed quantity of heat between definite temperature limits, it is obvious that the higher the maximum temperature the smaller the volume of water required. The boiling-point of water rises as the head or pressure to which it is subjected. At atmospheric pressure the boiling-point of water is 212° F., but under a head due to an overhead supply cistern, say, 100 ft. above the storage cylinder, boiling-point is about 290° F., thus under these circumstances the water could be raised to a temperature of 270° without generation of steam.

The variation in boiling-point of water with pressure is as follows :—

Head in Feet	*Pressure in Lb. per Square Inch*	*Boiling-point °F.*
20	8·6	236
30	13·0	246
40	17·0	254
50	21·0	261
60	26·0	267
70	30·0	274
80	35·0	280
90	39·0	286
100	43·0	290

For Radiator Systems

Most radiator heating systems are designed to work with a flow temperature of 180° F., and a return temperature of 150° F. To maintain this flow, the lowest temperature to which the stored water may fall is 180° F. If storage cylinders were worked at a maximum temperature of 270° F., each gallon of water can cool 90° F., in doing which, 90 × 10 = 900 B.Th.U. will be liberated. The total storage volume required for any building can be obtained by dividing the total heat storage required, by the heat liberated during the permissible temperature drop. Take the case of a building requiring ·5 million B.Th.U. per hour for the maintenance of a temperature of 65° F., and current available for 12 hours at night. The total heat storage in this case must be 6 million B.Th.U. With the temperature limits of 270° and 180° F., the total capacity of the storage cylinders must be :—

$$\frac{6{,}000{,}000}{10\ (270 - 180)} = 6{,}700 \text{ gal. approximately.}$$

The temperature of the stored water at the end of the day's run is about 160° F.—the return temperature of the system, and the storage must be reheated during the 12 night hours to 270° F. To do this an electrical input of $\frac{6{,}700 \times 10 \times 90}{3{,}410 \times 12} = 150$ kw. is required.

Operation of the Plant

Thermal storage plants can be made entirely automatic. When the current is switched off, the primary pump is stopped and the secondary pump attached to the heating system is started, and the hot water from the storage pumped around the building. Sometimes, where the period of warming the building overlaps the off-peak hours, both sets of pumps may be running.

Now it is quite impracticable to send high-temperature water through a radiator system. An automatic mixing valve is inserted in the main-floor pipe, through which some water from the return pipe is by-passed and mixed with water from the storage cylinder. These valves are thermostatically controlled, so that if there is very little temperature fall between flow and return pipes, very little water is taken from the storage cylinders.

Panel Warming with Thermal Storage

It has been stated elsewhere (page 167) that the average flow temperature of hot-water ceiling panels is about 110° F. The advantage of using panels in conjunction with thermal storage plant is that smaller storage cylinders are required. Take, for example, the case outlined above. The total heat requirements of the building are stored between temperature limits of 270° F. and 180° F. for a radiator system : for a panel system the temperature limits would be 270° to 110°. In this case,

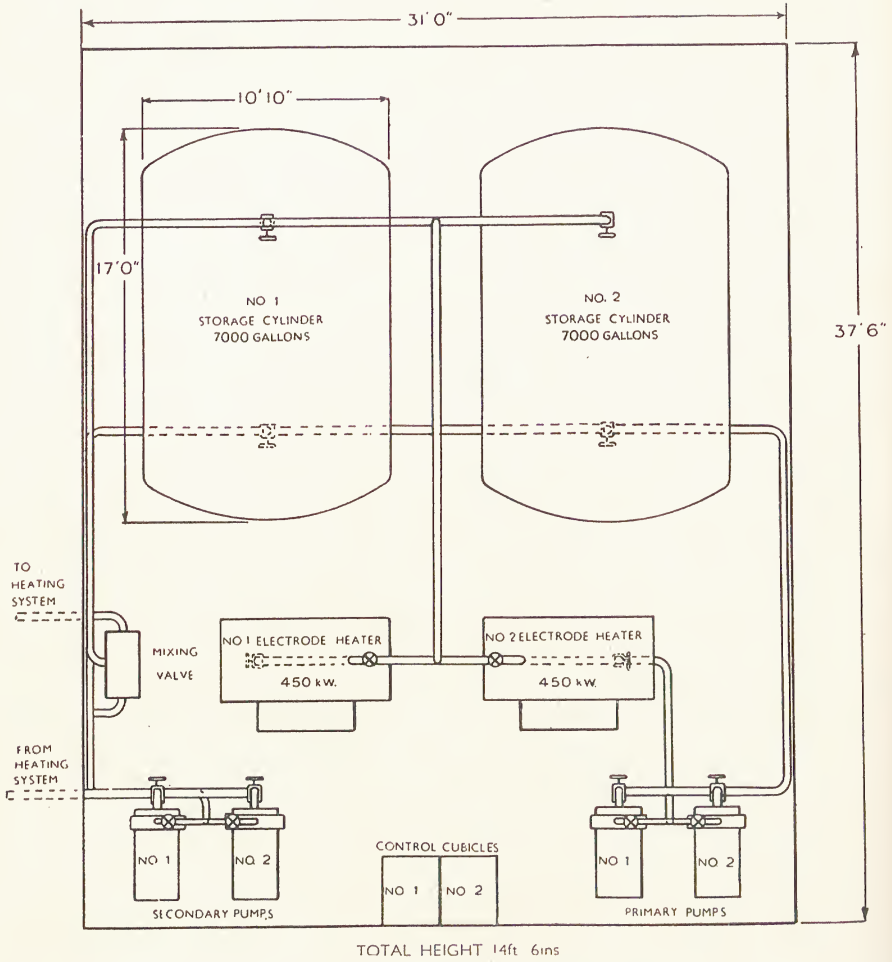


Fig. 4.—TYPICAL BOILER-HOUSE LAYOUT OF ELECTRODE THERMAL STORAGE PLANT FOR HEATING BUILDINGS

A flow diagram is shown in Fig. 5.

each pound of water now contains $(270 - 110) = 160$ B.Th.U. and each gallon, therefore, $160 \times 10 = 1{,}600$ B.Th.U., and the total capacity of the storage cylinders must be $\frac{6{,}000{,}000}{1{,}600} = 3{,}750$ gallons.

Estimating Consumption

On page 303, dealing with thermostats, the variation in the outside winter temperature in England was indicated, and it will be remembered that the heat loss from a building is calculated for a definite temperature

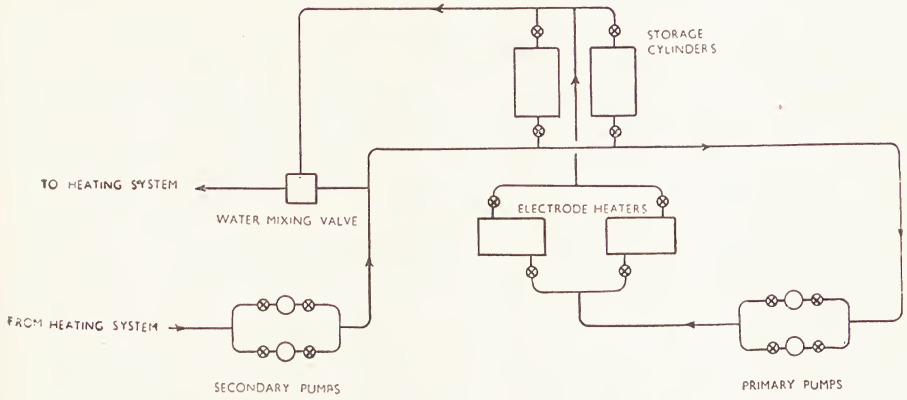


Fig. 5.—Flow diagram of piping for plant shown in Fig. 4

difference of, say, 30° F. between inside and outside temperatures. If the outside temperature is above 32° F., then—assuming automatic control—the thermostats will cut off the heaters for certain periods. As the outside temperature rises, the operation of thermostats becomes more frequent. It is known from experience that the average demand of a building over a season is approximately 55 per cent. of the maximum possible, the maximum being represented by 200 days' or 5,000 hours' heating season, multiplied by the net calculated load—exclusive of extra allowances—of the building under consideration.

Continuous *v.* Intermittent Warming

It is often claimed that the provision of a time-switch, for switching on the installation at some pre-determined time in the early morning, thermostatic control also being used, results in appreciable economies over continuous warming. While this is true when considered purely from annual consumption point of view, the conditions of comfort produced by 24-hour warming are always greatly superior to those ever obtained by any intermittent heating. A comparison between the two results is therefore not justified. Although a thermometer may show equal readings for air temperatures, the fabric of an intermittently heated building can never become thoroughly warmed. The temperature of the walls plays an important part in producing comfortable conditions, and these never become warm enough for ideal conditions in intermittently heated buildings.

For the best and most economical results some heat should always be delivered to a regularly used building over-night. The maintenance of a temperature of about 50° F. to 55° F. during the unoccupied hours brings the temperature rise to, say, 60° F., well within the power of a normal load.

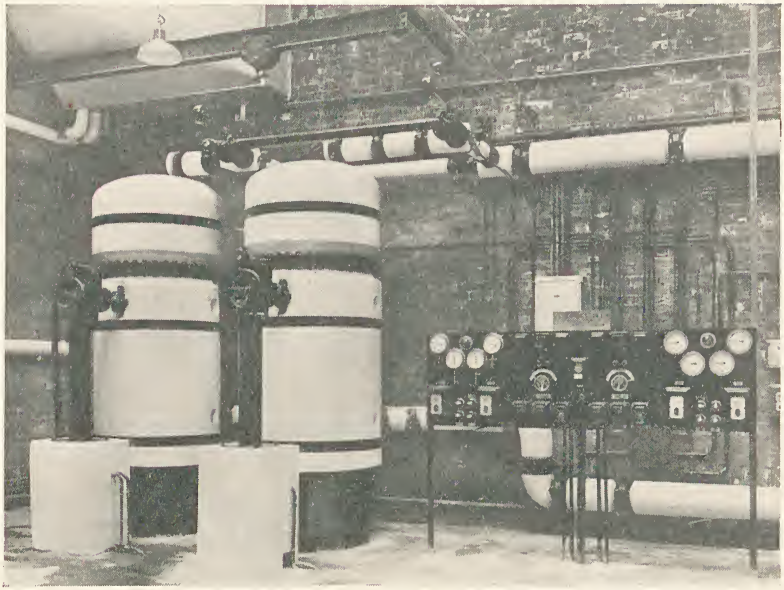


Fig. 6.—TWO ELECTRODE WATER HEATERS OPERATING AT HIGH VOLTAGE

Here we see two 1,000-kW. 6,000-volt-type water heaters and control panel, installed for Knightswood Bus Garage thermal storage heating. Two heaters are often desirable in preference to one larger heater, as this allows one to be shut down during summer. Note that more headroom is required for high-tension heaters. (*A. Reyrolle and Co. Ltd.*)

This is what happens with a hot-water central-heating installation when the fire is banked over-night, and can be made entirely automatic with either direct or storage electric-heating systems.

HEATING AND VENTILATION

PART VII.—BUILDER'S WORK INCIDENTAL TO THE INSTALLATION OF HEATING AND VENTILATING SYSTEMS

THE amount of builder's work required in connection with heating and ventilating installations varies considerably, and should always be carefully considered by the designer of the proposed installations, not only from the point of cost, but with regard to the practical difficulties that may be encountered.

In an existing building that is to be centrally heated, the amount of cutting away should be kept to a minimum, as there may be unsuspected obstacles to fixing the pipe runs as planned unless a very careful survey has previously been made. This applies particularly to pipes intended to be fixed below floors.

Where the building is a new one, some collaboration between the architect, builder, and heating engineer is advisable, especially when dealing with some of the larger buildings. Electric conduits, gas and cold-water pipes, and other sub-contractor's fittings have all to be accommodated in the building, and a little co-operation among the parties will often result in a considerable reduction in the number of chases and pipe trenches.

Plans showing the positions and sizes of holes through walls and floors, etc., should be prepared at the earliest possible moment after the contract has been placed, and copies sent to the architect, clerk of works, and builder. Arrangements can then be made for suitable provision for pipes during the construction of the building, which will eliminate cutting chases and holes in the walls after they are built.

Boiler Chambers

The builder's work in the boiler chamber includes the construction of a boiler base, which should be of blue brick and of a size suitable for the boiler. Most boiler manufacturers give details of boiler bases which they recommend, but the dimensions are often at variance with the sizes possible to obtain by using stock-size bricks, and one should endeavour to assist the bricklayer in such instances by making some modifications to the boiler-maker's dimensions.

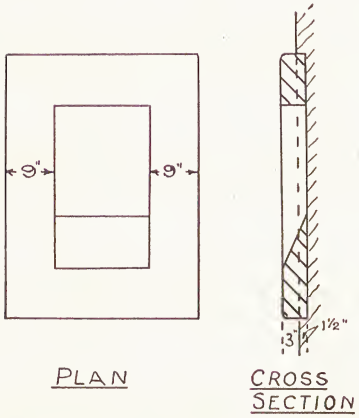


Fig. 1.—TYPICAL ARRANGEMENT OF BASE FOR HEATING-BOILER

Boiler Bases

Boiler bases for sectional boilers are usually constructed as shown in Fig. 1, from which it will be noted that the bricks are set on edge, 3 in. above floor and $1\frac{1}{2}$ in. below. By fixing the bricks $1\frac{1}{2}$ in. below floor level, the base is strengthened, as the possible loosening of the bricks from knocks by the shovel or poker is prevented. After the boiler has been erected, any possible air leakages to the ashpit should be stopped by a cement grouting round the base.

Smoke Pipe

In building in the smoke pipe, care must be taken to see that the end of the pipe does not project beyond the inner face of the brickwork into the flue, as this may restrict the area to an extent beyond that necessary for the required volume of gases to pass out from the boiler (see Fig. 2).

A thoroughly airtight joint between the brickwork and smoke pipe is also essential for the maintenance of an effective draught.

Provision for sweeping the chimney is made by building in a cast-iron door and frame either below or above the smoke pipe. If below the smoke pipe, the height from the floor to the level of the cleaning-door must be sufficient for the sweeping rods to enter the chimney at an angle of not more than, say, 30° from the vertical.

If the cleaning-door is built in above the smoke pipe, provision must be made for cleaning the pocket so formed from cleaning-doors fitted to the smoke pipe.

The chimney should never extend below the smoke pipe or cleaning-door, whichever is the lower.

Bases for Pumps

Bases for pumps or accelerators are usually of concrete, and where silent operation is necessary are often insulated from the floor by some sound-absorbing or anti-vibration material, such as cork. The engineer's instructions to the builder in this respect should be quite clear, and it is the rule for the engineer to supply whatever anti-vibration material is required. Any holes necessary for holding-down bolts should be left for the bolts to be grouted in after the machine is in position.

The position and horse-power of any electrical equipment to which the electricians must carry mains and make connections should be indicated on the drawings submitted to the architect and general

contractor, in order that a clear understanding shall exist that such work—outside the heating engineer's contract—will be necessary.

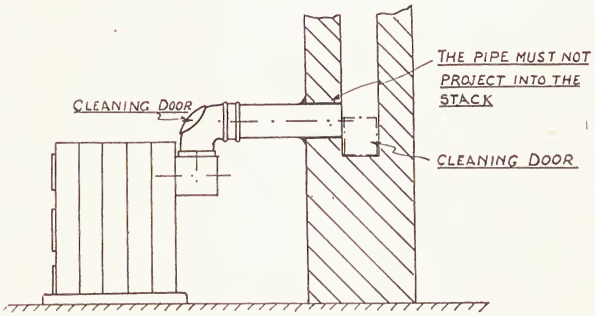


Fig. 2.—SMOKE-PIPE CONNECTION TO BRICK CHIMNEY

Drain

One other item of importance in the consideration of the boiler house, is the drain. A drain is necessary to carry away any water that may be drawn off from the boiler when the system is emptied down for alterations or repairs, and the gully should be so positioned that it will not be covered over with fuel or ashes.

Naturally, the floor surface should slope downward slightly towards the gully, which should be at the lowest point.

In some basement boiler chambers, the floor level is below the main drainage system, and it is then advisable to form a sump, not less than 18 in. by 18 in. by 18 in., which can be emptied either by a small, electrically operated pump or by a hand-operated semi-rotary pump.

TRENCHES, CREEPING-WAYS, AND CHASES

Where pipes are fixed under solid floors, suitable trenches or creeping-ways must be formed. In fairly large systems a subway may have to be constructed for the accommodation of the pipes for all the services and electric mains. A subway differs from a duct or creeping-way in that it is of sufficient height for a man to stand upright in it, and is therefore not less than 6 ft. high.

A pipe duct or creeping-way is also used for electric mains and the pipes for services other than the heating system. It should not be less than 3 ft. high, and 2 ft. 6 in. should be regarded as a minimum width. If pipes are fixed on both sides, the width may have to be 3 ft. 6 in. or 4 ft. to permit the unrestricted use of pipe wrenches, etc.

Sizes of Pipe Trenches

The minimum dimensions of pipe trenches must be considered to be 6 in. by 6 in., which is large enough for one pipe of, say, not more than 2-in. bore ; if larger, or more than one pipe is to be fixed in the same trench, the size must necessarily be increased. In determining the sizes of trenches, accessibility to the bottom pipe must be considered, also the space occupied by lagging or flanges.

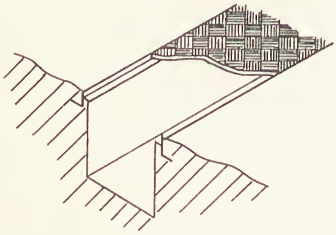


Fig. 3.—CHEQUER-PLATE TRENCH COVER AND RAILS

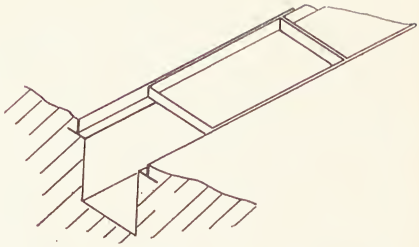


Fig. 4.—DISHED-PATTERN TRENCH COVERS.

Trench Covers

Trench covers may be of removable metal plates or of precast concrete slabs. Metal covers are usually of cast-iron or mild-steel chequer plates, supported by cast-iron rails built in on each side of the trench, as shown in Fig. 3.

Another pattern is the dished cover or tray (Fig. 4), which can be filled with the same material as that used in the finish of the remainder of the floor. This is obviously a more suitable pattern for important rooms or corridors, as, except for the metal edges of the rails and trays, the finished surface of the floor is not marred by a cast-iron track 9 in. or 12 in. wide.

Precast concrete covers are suitable for trenches in passages or yards, and for outdoor purposes. After the pipes are in position, the covers are set in cement and are not readily removable. Access covers should be provided at suitable intervals, and at points where valves are fixed.

In all cases, accessibility to the pipes is an advantage, and will save time and temper if repairs or alterations are necessary.

Creeping-ways

If pipes have to be fixed in creeping-ways after these have been covered down, the builder should be instructed to leave holes either at the end or at other convenient points so that lengths of approximately 15 ft. or so can be passed through. Such holes must be left in each straight run of duct if the width is insufficient to permit a corner being turned.

The attention of the builder must be drawn to the importance of the effective draining of subways, ducts, and trenches by the provision of suitable gullies.

Pipe Chases

For the concealment of vertical pipes, chases are cut or left in the walls. The minimum size suitable for, say, a $\frac{3}{4}$-in. pipe, and allowing sufficient space for the pipe wrench, is $4\frac{1}{2}$ in. by $4\frac{1}{2}$ in. The width must of course be increased where more than one pipe is to be fixed in the same chase.

Chases are usually formed in the corners of rooms in the main wall, and may be covered either by a removable board fixed flush with the plaster and fastened by screws, or by expanded metal, wood-fibre boarding, or similar material which can be permanently plastered over.

Pipe and Radiator Brackets

These are usually built in to the engineer's instructions on site. Pipe brackets should be carefully lined if they are not of an adjustable pattern, or the weight of the pipe will be taken by only a proportion of the brackets, which will then have to bear a load greater than that for which they were designed.

Radiator brackets should be built in so that the radiator supported by them stands vertically, and if fixed under a window or in a recess takes up a central position.

Deflecting Shelves

These are sometimes fixed above radiators to prevent discoloration of the wall. If of sheet metal the shelves are usually supplied by the engineers, but if of hardwood they are supplied and fixed by the builder. An airtight joint between the wall and shelf is essential, and if there is any irregularity in the plaster surface, a suitable jointing material should be provided.

Holes through Floors and Walls

Where pipes pass through floors and ceilings, and plastering is done after the pipes are fixed, care should be taken to make sure that a space is left between the pipe and plaster. If the plasterer fails to do this, the movement of the pipes, due to expansion and contraction, will undoubtedly result in the formation of cracks in the plaster, if not in more serious damage.

Sleeve pipes should always be built in where pipes pass through walls. These may be of odd lengths of pipe of a size large enough to slip over the heating pipe. Galvanised sheet-metal sleeves are commonly used, but perhaps the pattern most favoured by consulting engineers is that known as Hall's pipe sleeve and thimbles. This consists of a short piece of iron pipe of the required length, screwed at each end, and fitted with specially designed cast flanges or thimbles, as they are termed (Fig. 5).

Feed Tanks

It may be necessary to build in brackets for supporting the feed tank, and although these are usually provided by the engineer, the builder should make certain that they are built in firmly enough to carry the tank when filled. A cold-water supply pipe must be carried to the tank, and a connection made to the ball valve fitted by the engineer. The provision

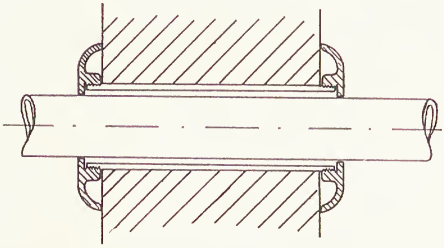


Fig. 5.—SECTIONAL ARRANGEMENT OF PIPE SLEEVES AND HALL'S THIMBLES

of this pipe is usually part of the builder's work, which should also include the fixing of a suitable stop-tap.

If the overflow pipe is carried through the roof, the necessary lead flashing must be provided to prevent any possible leakage of rain-water.

As a precaution against freezing, it is sometimes advisable to encase the tank with a wood enclosure, and to pack the space between with wood-dust or other material having good non-conducting properties.

Painting

All exposed pipes and radiators require at least two coats of good heat-resisting paint, and in some cases it is left to the builder to paint the non-conducting composition that has been applied to the boiler and pipes. The colour of paint makes little difference to the heating effect of radiators, but as pointed out on page 33 of this volume, paints having a metallic base, such as bronze or aluminium, reduce the heating effect by about $12\frac{1}{2}$ per cent.

When considering the painting of mains in subways and boiler houses on large contracts where there may be a number of pipes of similar size, it is a good plan to give the various services distinguishing colours. It is then possible to recognise, say, a gas main or cold-water pipe immediately, and dispenses with the necessity for labels or the laborious tracing of pipes from or to recognised points. The Engineering Standards Committee has published a list of colours which it recommends be used, but provided colours of sufficient contrast are chosen, and the maintenance engineer is supplied with a suitable chart, any selection may be made.

VENTILATING SYSTEMS

The amount of builder's work necessary in connection with ventilating schemes depends largely on the type of installation. If a simple extraction system, comprising a propeller fan discharging the air from a small hall is under consideration, all that may be necessary on the part of the builder will be the provision and building in of a suitable wooden frame against which the fan is to be bolted.

More elaborate schemes will obviously require the assistance of the builder to a greater extent, and this may include : the cutting of holes through walls, and building in gratings and registers to form fresh-air inlets ; the formation of airducts in either brickwork, concrete, woodwork,

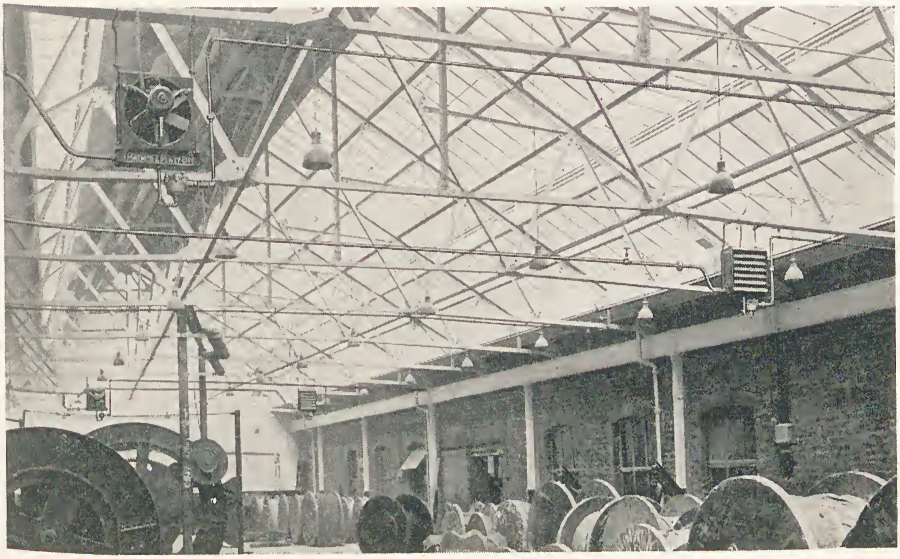


Fig. 6.—UNIT HEATING

Four steam-heated unit heaters shown installed in the roof space of an electric-cable store. Note that the supply and return pipes are installed as high as possible, necessitating a lift-type steam trap in each condense return (see page 183). (*Mather & Platt Ltd.*).

or plaster ; the construction of fan chambers and turrets, and the manufacture of specially designed extraction grilles if these are of fibrous plaster. If the grilles are of metal, they are usually supplied by the engineer and fixed by the builder.

Particulars of the electrical power required must be given, if, as is commonly the case, the fans are electrically driven.

When Builders'-work Ducts Are Used

It is frequently desirable to construct in builders'-work a proportion of the ducts in a large modern building. Although usually more costly than metal, such ducts may be desirable for three purposes :—

(1) Under floors, where metal ducts would be unacceptable and liable to external dampness and corrosion.

(2) Vertical shafts, where builders'-work casings would in any event have to be provided around metal ducts, to which access would be difficult.

(3) For purposes of noise elimination.

Builders'-work ducts are frequently used underneath the basement floors of large hotels, cinemas, theatres, etc., and for main air ducts.

One of the difficulties encountered by the heating engineer when this type of duct work is used, lies in the difficulty of ensuring that a reason-

ably smooth internal finish is provided by the builder. When the finish is rough, considerable friction is set up, causing a wastage of power and regulation difficulties, since in the calculations for the system sufficient allowance will probably not have been made.

A more serious difficulty occurs if roughly finished ducts are used for extract air, for the sides of the ducts become covered with dirt.

Where Builders'-work Ducts Should Not Be Used

On no account should builders'-work ducts be used in the extraction systems from kitchens or press-rooms, for in each case a considerable amount of grease is carried into the system and the ducts in time become coated with a thick layer which not only reduces the volume of air dealt with, but introduces a serious fire risk. Full provision should be made for cleaning in positions where extracted air is laden with greasy particles which are likely to coat the ducts.

Uralite or Asbestos Ducts

In certain instances extracted air will contain fumes which cause corrosion to metal, and in these cases Uralite or some form of asbestos construction is desirable.

Generally

The heating and ventilating engineer, in common with other specialist sub-contractors, must give the building contractor full details, at an early date, of any special requirements for the accommodation and successful performance of his plant.

The builder is expected to provide all scaffolding and ladders for the use of the engineer, and to clear the site of all rubbish on completion.

COOKING EQUIPMENT AND INSTALLATION

THE essential factors relating to sizes and position of kitchens for hotels, which must be considered by the architect to enable specialised fittings and equipment to be properly installed, are described on page 218, Vol. I.

Layout of Kitchen

It will be seen from the layout in Fig. 1 that the main kitchen is divided into sections. Dirty crockery returned is delivered directly into the wash-up. Vegetables are prepared and cooked in a separate room. From both of these processes large quantities of steam are liberated, and whether the equipment be gas, electric, or steam heated, it is desirable to keep this steam away from other parts of the kitchen. The pastry room is seen next to the cold store. This is because pastry demands a cool atmosphere. For this reason pastry-preparing tables should have marble or smooth stone tops. For the rest, the plan shown in Fig. 1 is self-explanatory.

Before dealing with the actual cooking equipment there are several important points requiring attention in connection with the kitchen services.

Ventilation

By the use of extract fans, not only can the atmosphere be prevented from becoming excessively humid, but smells can be prevented from passing beyond the kitchen walls.

The usual practice is to deliver fresh air at the rate of about 10 air changes per hour, and extract at the rate of about 20 changes per hour.

Architectural Details and Lighting

In those sections where there is an excess of free water due to condensation of steam, a slight slope in the floor, terminating at a gully or drain, should be provided. The floor should be of the easy-cleaning but non-skid type. Walls should be finished in white, to give the maximum of reflected light. White glazed bricks are admirable from an hygienic and illuminating point of view.

Artificial lights should be fixed directly over the various units of equipment, as far as is practicable.

TYPES OF EQUIPMENT

The types of cooking equipment available can be classified as solid-fuel equipment—burning coal or coke; oil or gas fired, or electric equipment. Many equipments are a combination. For example, coal-fired ovens and steam-heated vegetable steamers and hot cupboards may be used. In some cases, electrically heated ovens and grills are used in conjunction with gas boiling ring, while vegetable cookers and hot cupboards are steam heated. These combined equipments are usually the result of long experience, which gives to a chef or engineer particular liking for certain types of heating for certain processes, but they seldom produce more economical results than are obtained by use of straightforward equipment. A further disadvantage is that a piece of equipment, such as a range, with electrically heated ovens and gas rings, is non-standard, and therefore adds to the capital cost of the plant. An architect is on safe ground in recommending to his client one of the following equipments: (*a*) all electric; (*b*) all gas; (*c*) steam-electric; (*d*) steam-gas.

The selection of type of equipment is to some extent influenced by the equipment required for the other parts of the building. It would not be economical, for example, to install a steam boiler purely to supply steam for kitchen use. If steam is required for warming the building or hot-water supply or perhaps a laundry, then there are economies to be obtained by the installation of steam equipment in the kitchen.

Every piece of equipment used in a kitchen can be either electrically driven or electrically heated; gas can be used for kitchen heating processes. The use of steam is limited to still-room equipment—hot cupboards, *bains-marie*, vegetable ovens, stock-pots, etc.—and cannot be used for roasting, grilling, or fish frying.

Relative Costs

While capital cost has some influence upon the selection of plant, the cost of operating the equipment is of vital importance. Architects are desirous always of protecting the interests of their clients by recommending the best type of plant to use. Whether steam is used or not, the debate is always between gas and electricity for the above-mentioned services.

It has been authoritatively stated, and experience with a great many equipments of all sizes gives proof, that where a unit of electricity can be purchased for one-tenth of the cost of a therm of gas, the advantages obtained from the use of electricity indicate that that type of heating could be economically used. Where electricity is obtainable at one-twelfth of the price of gas, then some definite saving is obtained by the use of electricity. Beyond this it is impossible to state any actual figures. The consumption of any piece of equipment will depend upon the extent of its duties and, of course, upon the nature of the meals provided.

The hourly consumption of a piece of plant, as indicated by its loading, is no guide as to the consumption of current over a period or under working conditions. For a double-oven range with boiling-plates, working under normal conditions, the average load is seldom more than 30 per cent. of maximum for the period during which it is used. This results from an intelligent use of the 3-heat switches and temperature maintenance only for cooking processes. Some results collected by S. C. Hurry and W. E. Swale, for a paper given before the I.M.E.A. Convention, 1936, are shown in the following Table. This paper, which is available in printed form, is valuable to architects interested in the question of electric cooking for large kitchens. These figures must be regarded as an indication only.

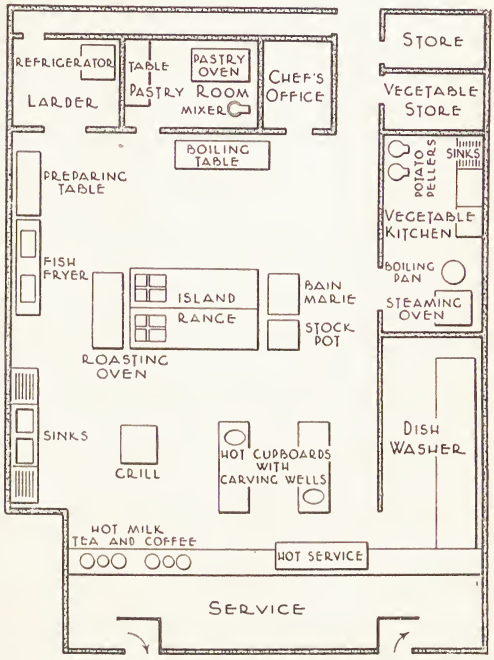


Fig. 1.—TYPICAL LARGE KITCHEN LAYOUT

	Building Served				
	Hospitals, Public Health Institutions	*Residential Clubs, Hotels, Service Flats*	*Restaurants, Cafés*	*Staff and Works Canteens*	*Non-Residential Schools and Colleges*
Number of selected cases	8	7	8	8	5
Average connected load in kw.	77	132	180	91	114
Average maximum demand of connected load per cent. kw.	58	53	47	63	64
Average consumption per installation kwh.	55,262	216,203	187,213	58,996	48,337
Average consumption kwh. per annum per kw. connected	716	1,620	1,037	648	422

STEAM COOKING

Apart from roasting, baking, grilling, and frying, most of the cooking processes can be effectively and economically undertaken by the use of

steam-heated vessels. These may include some or all of those given in the following list :—

Soup Boilers	Pudding Steamers
Fish and Potato Steamers	Milk Sterilisers
Vegetable Boilers	*Bains-Marie*
Stock Pots	Steam Kettles

Soup Boilers

These are usually of cast iron and may be of varying capacities, from ten to one hundred gallons. Each boiler consists of an outer vessel mounted upon legs or a single pedestal, and provided with tappings for the steam and condense pipes. An inner pan is bolted to the outer casting and the space between forms the steam-jacket. At the bottom of the inner pan an opening is formed and is extended through the side of the outer pan and fitted with a draw-off cock.

The latter should be of the plug type, and fitted with a cleaning plug in the bib.

Near the top of the boiler a vapour outlet is provided to which a pipe is attached and carried outside or to a flue. This prevents an excessive escape of steam into the kitchen and possible harm to the cook from the rush of steam from under the cover when this is lifted.

A hinged copper cover, heavily tinned on the under side and fitted with balance gear, completes the assembly.

Bloom-steel sheets are sometimes fitted round the outside of the boiler to reduce heat losses by radiation, and the space between may be packed with non-conducting composition.

For a product having a high-class finish and a rustless interior, the copper cover and lagging sheets may be nickel- or chromium-plated, and the inner pan cast in monel metal.

Fish and Potato Steamers

These fittings may consist of one large or an assembly of small steam-heated ovens. Their capacities are usually stated in pounds of potatoes, and range from 25 lb. to 400 lb. In the assembly of small ovens there is the advantage of using the different compartments for various purposes ; thus, one or two may be used for potatoes and the others for fish or pudding steaming.

Steam is admitted at pressures not exceeding 2 lb. per sq. in. and enters the oven through an opening of comparatively large area, which has the effect of reducing the steam velocity.

An outlet for the condensate is connected by pipework to the steam trap. The trap is usually a combined grease and steam trap with the outlet carried to a drain. It is inadvisable to return the condensate to the hotwell.

The door is bolted and made steamtight by the provision of suitable

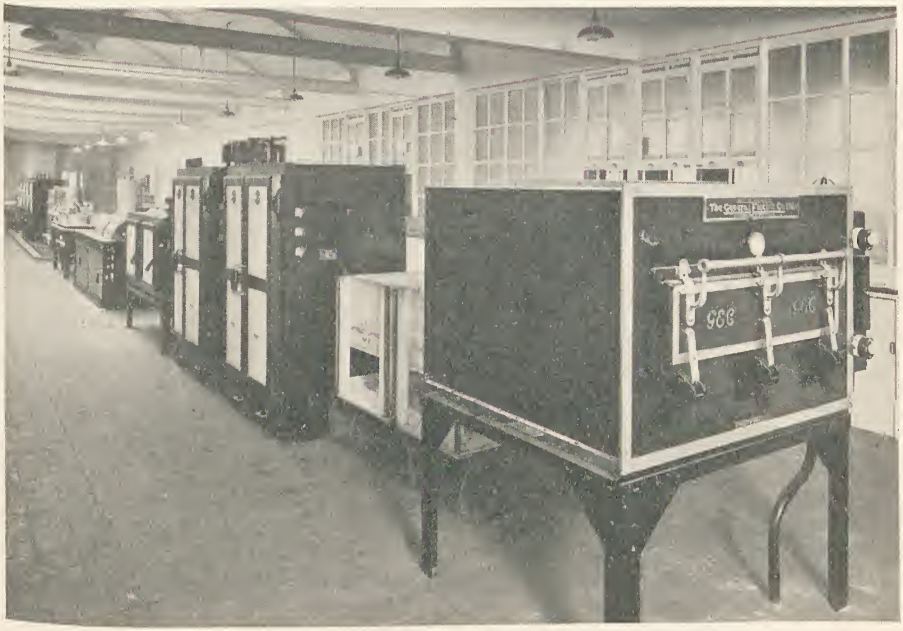


Fig. 2.—AN ALL-ELECTRIC KITCHEN FOR WORKS CANTEEN

At the G.E.C. factories, Wembley, providing for canteen 160 ft. long and 50 ft. wide and accommodating 1,000 people, in addition to a restaurant for 200 people. The kitchen staff comprises 3 cooks, assisted by 15 maids. (*General Electric Co. Ltd.*)

jointing material which is inserted into a groove surrounding the oven opening and against which the door presses when closed.

It is usual so to arrange the steam valve that it must be closed before the door can be opened. The valve is of the plug type with the ports designed to open the exhaust pipe at the same time as the steam pipe is closed. These are necessary safeguards against the possibilities of injury.

As a further precaution against excessive pressure, which might result from the failure of a reducing valve, a safety valve of adequate area should be fitted to each compartment.

Vegetable Boilers

These are identical with soup boilers except that in addition they are sometimes provided with wire baskets or crates for holding the vegetables. After cooking, the vegetables are lifted out in the crates and carried over to a draining stand. For the larger boilers, overhead travelling gear and pulleys are used for lifting the crates of vegetables.

Stock Pots and Milk Sterilisers

As it is desirable that the contents of these vessels should not boil, water-jacketed pans are provided. In the water-jacketed boiler, the

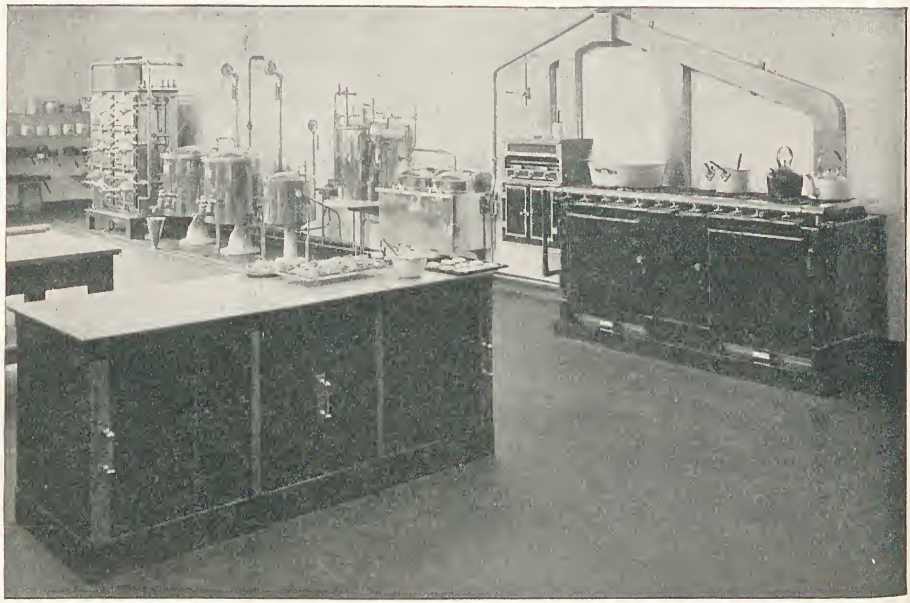


Fig. 3.—STEAM COOKING KITCHEN

Showing hot plate and closet, cooking stove, boiling pans, and steaming ovens in position. (*G. N. Haden & Sons Ltd.*)

space between the inner and outer pans is filled with water which is heated from a steam-heated pipe-coil fitted at the bottom. The water inlet is sometimes placed near the top of the outer pan and is of fairly large diameter so that it forms both a water inlet and a vapour outlet. The water level is maintained from a supply tank fitted with a buoy valve. The height of the tank is adjusted to the required water level.

When required for use as milk sterilisers, the boilers are usually fitted with white enamelled inner pans.

Bains-Marie

A *bain-marie* is a shallow bath filled with water which is heated from a steam space or coil provided at the bottom. Small pots are placed in the bath and contain the soups, etc., which have been prepared before the meal is served. By this means, the liquids are kept hot until such time as they are required.

Steam Kettles

Quantities of boiling water are of course necessary for culinary requirements as well as for tea and coffee making. A steam kettle is, therefore, an important fitting to include in the kitchen equipment.

Some patterns are designed to give practically an instantaneous

supply of boiling water ; others, having a larger capacity, heat up the contents in a given time, and are then emptied and refilled as required.

The instantaneous boiler is often arranged to be more or less automatic in action. Steam and water are turned on simultaneously by the same handle, and one of the usual features is that no water can be drawn off until it is boiling.

Steam kettles are generally of copper, tinned on the inside, and fitted with steam-heated copper pipe-coils also tinned. In the non-automatic type, a thermometer and water-gauge are provided, and in addition a vapour outlet pipe of adequate area. For ensuring economy in the consumption of steam, a thermostatic control valve is sometimes fitted.

Hot Closets and Serving Tables

A hot closet and carving table in one unit, is commonly provided in the kitchen servery. The closet or cupboard may be of varying lengths from 3 to 10 ft. ; the width 2 ft. 3 in., and the height 2 ft. 9 in. Sliding doors on one or both sides are fitted, and there is usually one or more shelves of perforated sheet steel. Steam-heated chests or pads of cast iron are fitted at the top and bottom with the usual connections for the steam and condense piping.

The upper surface of the top casting is ground and is used as a serving table. One or more shallow wells may be formed in the top plate for the purpose of holding the joints of meat.

Steam Pressure

The steam pressure for kitchen equipment is usually not more than 15 lb. per sq. in., and unless they are specially designed, serving tables and hot closets, because of the large flat surfaces, should not be subjected to more than 5 lb. per sq. in.

In steaming-ovens, the pressure should not exceed 2 lb. per sq. in.

It is necessary, therefore, to provide reliable reducing valves in the pipe-lines to the fittings working at lower pressures than the remainder of the equipment.

ELECTRIC COOKING EQUIPMENT

An All-electric Kitchen

Fig. 2 shows an example of an all-electric kitchen for a works canteen accommodating 1,000 people, and for a restaurant for 200 people. The equipment comprises : 2 cabinet roasting ovens—each oven taking 300 lb. of meat at one charge ; 1 double-oven range ; 2 boiling tables, equipped with G.E.C. high-speed boiling plates ; 1 single-deck baking oven, for cakes, pastries, etc. ; 2 16-gal. stockpots ; 2 20-gal. vegetable boilers ; 4 steaming ovens ; 1 three-pan fish fryer, complete with canopy and draining racks ; 5 hot cupboards, 8 ft. 6 in. long ; 1 hot cupboard, with

Fig. 4.—THE STEAM SOUP-BOILER

The lid is raised to allow filling. Note hot soup draw-off cock and steam inlet at bottom of boiler. (*G. N. Haden & Sons Ltd.*)

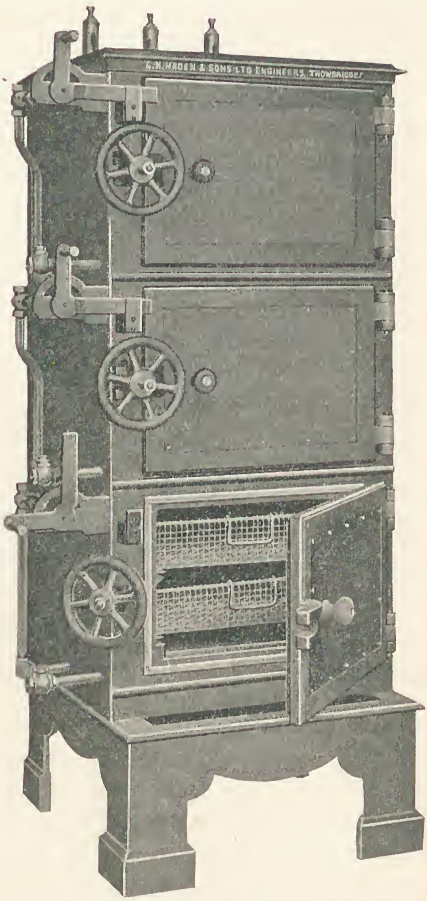


Fig. 5.—FISH AND POTATO STEAMER

Note that the above example consists of an assembly of steam-heated ovens. (*G. N. Haden & Sons Ltd.*)

two carving wells and covers in monometal; 2 hot cupboards, 6 ft. 6 in. long; 1 large toaster; and 1 large griller on stand.

Auxiliary units include: 1 electric washing-up machine; 1 electric mixer; 1 electric potato-peeler; 1 electric slicing machine; and 1 electric refrigerator.

The hot-water equipment comprises: 2 banks of G.E.C. storage water heaters, each 80 gal., feeding sinks; 2 100-gal. heaters feeding the dish-washer; 1 30-gal. heater in ladies' lavatory. By the serving-hatches to the canteen two standard cafeteria sets are installed for dispensing tea, coffee, and milk. The total cooking load is 250 kw.

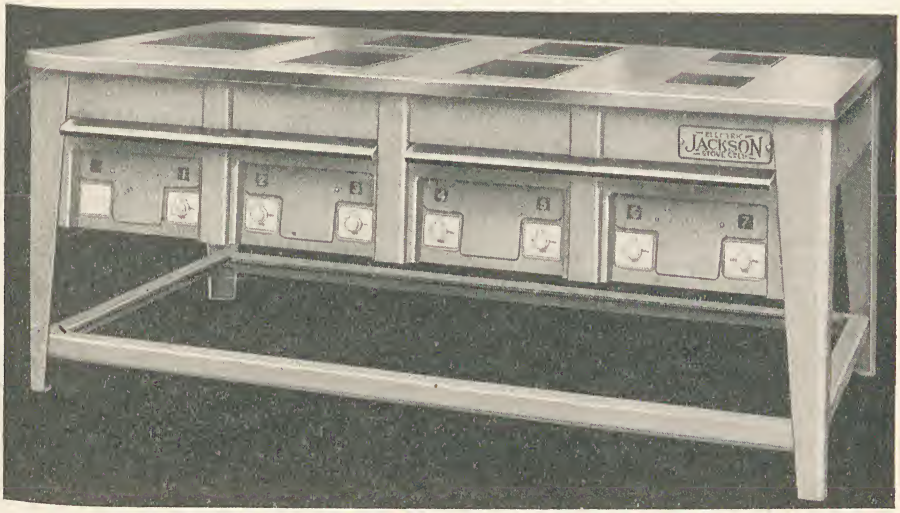


Fig. 6.—AN ELECTRIC BOILING TABLE
This is built at a low level for convenience of working. (*Jackson Stove Co. Ltd.*)

Boiling Tables

Perhaps the most important items in any kitchen are the ranges. In many small hotel kitchens, this piece of equipment, with its hot plate and grill, together with one or two auxiliary pieces of equipment, constitutes the whole plant. For large kitchens, however, it is more customary to use cabinet roasting ovens and separate boiling tables. This is primarily because the separate boiling tables can be built to a much more convenient working-level. There are, however, ranges of heavy construction with low hobs, as will be seen from Fig. 6.

Ovens of electrically heated equipment are invariably double-cased and lagged with slag wool. The inner and outer finish is of vitreous enamel, side or top and bottom heating being provided, the elements being of the usual nickel-chrome wire mounted on porcelain formers. Each oven is provided with fuses and one or two 3-heat switches, and often pilot lights.

Hot Plates

The hot plates on large hotel cooking equipment are generally rectangular in shape, as this shape is more convenient for simmering purposes than circular plates—several pots may be kept at work on one plate. They are generally of the solid cast-iron-top pattern, although occasionally the radiant type is used. There is little to choose between the two types as far as performance is concerned. The chief claim of the radiant type is that almost any utensil can be used upon it, whereas with the

solid plate the heat transfer between plate and saucepan is by conduction. The saucepans should therefore have heavy, machined bottoms. While the advantage of using any utensils obtains for domestic installations, the utensils used in large kitchens are invariably heavily constructed. The radiant type of hot plate, protected though it is by a metal tube, is not so robust as the solid plate, which will stand much overheating for long periods and, contrary to general belief, give exceedingly rapid results.

Fig. 7.—ELECTRIC GRILL

The above example is split into two sections. (*Jackson Stove Co. Ltd.*)

On modern cooking equipment the connections to the hot plates are protected against liquids boiling over, and can come to no harm through this cause. To use a trade expression, they are " drench proof."

Cast-iron hot plates are built up of units to total dimensions of about 24 in. by 18 in., with a loading of 10 kw.—each individual plate being loaded to 2·5 kw. A 24-in. by 18-in. hot plate would be controlled by two 3-heat switches, giving a " heat " suitable for any cooking process.

Grills

The grills provided on double- or single-oven ranges, while of adequate area to meet the demands upon the kitchen of a small restaurant, are far too small for the needs of hotels ; separate grillers or salamanders are required. These are available in all sizes suitable for use in floor-maids' rooms or in main kitchens. The grill is an appliance the element of which must of necessity run at a high temperature, in order to produce the radi-

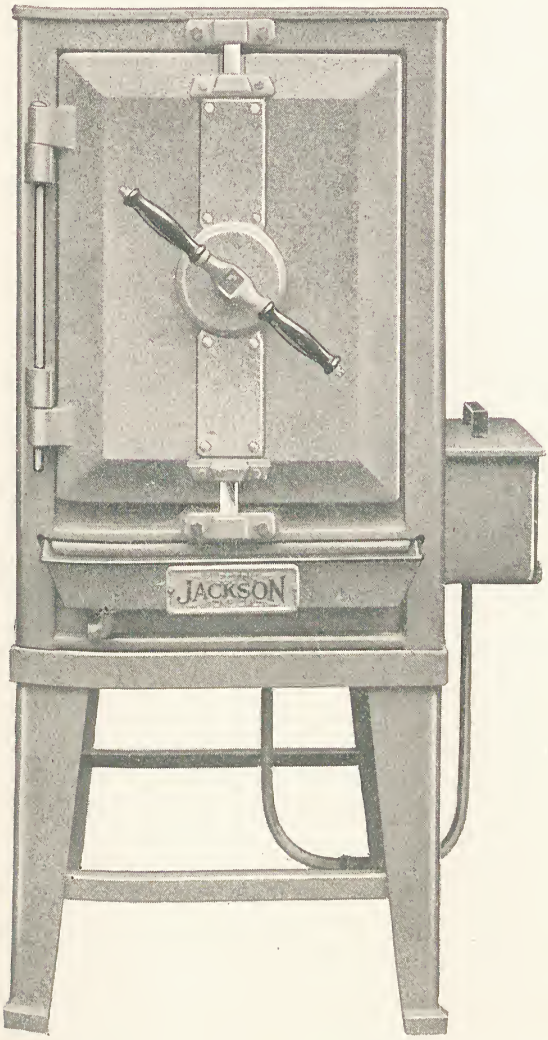


Fig. 8.—ELECTRIC STEAMING-OVEN
Complete with ball valve-tank. (*Jackson Stove Co. Ltd.*)

ant heat required for the cooking process. Large grills, which are often used as toasters, are split into two sections, each with its controlling switch.

Pastry Ovens

Only the larger of hotels have their own bakery, and some use the ordinary range for pastry purposes, but all well-equipped kitchens have a pastry oven. Electric pastry ovens may have up to three decks—this limit is imposed by the working height—and they differ from roasting ovens in that they have large area and small height. They have also vitreous-enamel interiors, with tile soles of refractory firebrick. These latter are a relic of the earliest of ovens ever built, and act as a kind of thermal fly-wheel to prevent wide fluctuation in temperature during loading and unloading the oven.

This type of oven usually has tubular elements running from front to back, and withdrawable from the steel casing at top and bottom of each deck; each set of elements is controlled by a 3-heat switch. Pilot lights and thermometers are usually incorporated.

Steaming Ovens

Electrically heated steaming ovens are self-contained, and generate their own steam. The bottom of the oven is provided with a water bath in which the water is kept at a constant level by means of a ball valve.

Water is heated by immersion heaters or clamp-type elements similar to those used in an ordinary electric kettle. The water in the bath is boiled, and the oven becomes full of steam at slight pressure. Tinned-wire trays are provided to carry potatoes or puddings. The door is fitted with a gasket and wedge-type bolts, which makes a steamtight joint. The principal difference between steam-heated ovens and electrically heated is that the former have a number of small compartments, against a large one for the electric type. This is because of the difference in working pressure.

Fish Fryers

Fish frying is one of those duties which cannot be carried out by steam. In electric fish fryers, wire baskets are used to carry either fish or potatoes, and the frying oil is contained in a heavy steel container which is removable from the body of the fryer for cleaning purposes.

The elements are of the open-coil type carried on porcelain formers, and there is an air gap between element and oil container. This air gap serves to equalise the temperature across the whole bottom of the oil container, and prevents overheating.

One of the incidental savings in the use of electric fish frying is that far less oil is needed over a period than with any other type of appliance. This is due to the absence of overheating and hot spots in the oil.

Hot Cupboards

For good service of hot food it is important that adequate hot cupboard space be provided for both hot plates and cooked food. For service, hot cupboards with heated tops, and carving well with covers and a *bain-marie*, which is used for keeping gravy, sauces, and the like, hot, is an excellent combination. Where carving-wells are provided with covers, provision must be made for fixing the rise-and-fall gear for the covers, as these work on counter-weights in very much the same way as a counter-balanced electric-light fitting. The cupboard, with sliding doors, is used for plates and carved meat.

Still-room Equipment

For the still-room, where the service of tea, coffee, and milk is carried out, there is an electrically heated appliance to meet all demands. There are coffee percolators of similar design, but of course larger than the domestic type, which should be silver-plated inside ; milk urns, with earthenware lining. This lining, which has rounded corners and is easily kept clean, is heated by a water jacket. The indirect method of heating prevents overheating of milk. For tea making there are urns and water boilers, which, while perfectly satisfactory for purposes within their scope, are apt to fall short of requirements when required to provide a continual supply of boiling water.

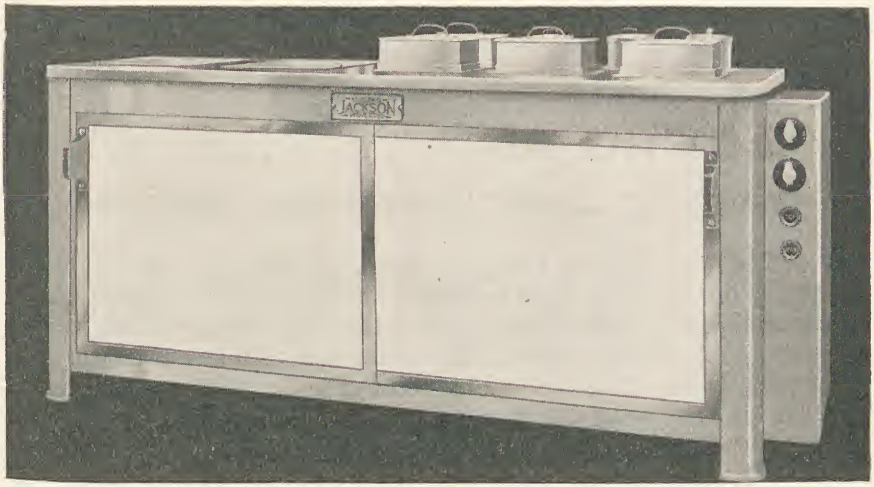


Fig. 9.—ELECTRIC HOT CUPBOARD WITH BAIN-MARIE. (*Jackson Stove Co. Ltd.*)

For a continual supply of water for tea making the so-called fountain boiler is ideal. This type of equipment is heated with immersion heaters and delivers only boiling water. One type is actually a small steam boiler, and works under pressures of the order of 3 to 6 lb. per square inch, and is usually provided with milk and coffee containers which are steam heated from the water container. If there is no pressure in the water container, water cannot be forced up the stand pipe to the tap. This type of boiler has the advantage that only when the water comes into atmospheric pressure is it boiling. Such equipment is fully automatic in action, being provided with ball-valve feed and pressure-operated switches which cut off the electric supply as the pressure rises or falls.

Another type of fountain boiler works on the expansion principle, and is automatic as regards water supply. The draw-off chamber is at the top of the heater, and so arranged relative to the main storage and heating elements that only boiling water can expand or bubble into the withdrawal chamber. If no water is withdrawn then the excess in the withdrawal chamber trickles back into the main storage. Thermostats are sometimes fitted to the main water storage, and immersion heaters switched by hand to give the final temperature rise just before withdrawal takes place.

Miscellaneous Appliances

There are many other electrically heated appliances among the necessities of a well-equipped kitchen. Chief among these are the stock-pot, which is but a larger edition of the ordinary domestic variety, plate warmers, egg poachers, and steamers, and other appliances.

HEATING AND VENTILATION

PART VIII.—VAPOUR-HEATING SYSTEM

LOW-PRESSURE steam- or vapour-heating, although not adopted so widely in this country as in America and on the Continent, can be successfully applied without causing the complaint, so often justified, of the dry, stuffy atmosphere usually associated with steam heating.

It is well known that the boiling-point of water is lowered at reduced pressures, as the Table below shows. It will also be noted that the volume of steam increases rapidly as the pressure is reduced.

Absolute Pressure lb. per sq. in.	*Vacuum in. of Mercury*	*Boiling-point °F.*	*Volume in cubic ft. per lb. of Steam*
14·7 (*Atmospheric Pressure*)	0	212	26·79
12	5·49	201·96	32·36
10	9·56	193·22	38·38
7	15·67	176·85	53·56
5	19·74	162·28	73·33
3	23·81	141·52	118·5
2·4	25	133	145·9

Knowledge of these facts is applied, therefore, in the design of vacuum systems of steam heating, where, by supplying steam at reduced pressures and carefully regulating the amount entering the radiators, it is possible to maintain them at temperatures considerably below 200° F.

The Boiler

The ordinary sectional-pattern boiler, similar to that used in hot-water heating, may be used, but care is necessary to make certain that the water level is maintained at the correct height. In addition to the usual water gauges, an automatic boiler feeder should be fitted to the boiler in systems where the return pipe is connected directly to the boiler. Where the condensate returns to a hotwell, automatic control gear fitted to the

feed pump regulates the quantity of water fed to the boiler according to requirements.

Piping Systems

The arrangements of the pipe circuits do not differ very much from those in hot-water heating.

Single-pipe

In the single-pipe system there is only one connection to each radiator, and this, as it has to carry the steam going in one direction and the condense flowing in the opposite direction, must be of an exceptionally large diameter. The circuit should rise to its highest point immediately above the boiler, and should fall from this point throughout its length to the return connection. Air relief valves are fitted approximately half-way up the radiators and are usually automatic in action, closing immediately steam reaches them. An air valve should also be fitted at the top of the vertical return pipe.

Two-pipe System

The two-pipe system is more generally adopted and embodies the provision of steam traps on the outlet of each radiator. On starting up, steam is generated at a pressure slightly above that of the atmosphere and flows through the steam main to the radiators. The steam, entering the radiators, condenses rapidly and thus induces the flow by the creation of a vacuum.

The air and water pass out through the traps which remain open until the radiator is filled with steam.

The Vacuum Pump

A vacuum pump connected to the return main enables the engineer to use smaller condense pipes and ensures a rapid flow of water from the traps. It may be steam- or electrically operated, and is usually fitted with some form of automatic control.

There are a number of patented fittings manufactured and marketed by various firms who specialise in steam-heating equipment. Some of these fittings require a special arrangement of pipework, and their inclusion results in a name, after the patentee or firm, being given to the system.

Comprehensive instructions and useful data for the proper installation of steam-heating systems embodying patented features are given in the manufacturers' lists.

Pipe Sizes

For sizing the steam pipes in low-pressure systems, reference to the following Table will serve as a useful guide.

LOW-PRESSURE STEAM PIPE SIZES

Diam. of Pipe ..		½ *in.*	¾ *in.*	1 *in.*	1¼ *in.*	1½ *in.*	2 *in.*	2½ *in.*	3 *in.*	4 *in.*
		Thousands of B.Th.U. per hour.								
Pressure drop in inches water gauge per 10-ft. run	1	3·5	14	30	55	98	170	320	510	600
	2	6·2	21	44	81	140	255	470	730	900
	3	8·5	26	54	100	166	320	570	890	1,080
	4	11	31	64	119	192	370	660	1,030	1,260
	5	12·5	36	72	133	215	420	740	1,170	1,410
	6	14	39	80	147	238	460	820	1,280	1,560
	7	15·5	42	86	159	260	500	890	1,380	1,700
	8	17	45	93	171	275	535	950	1,470	1,830
	9	18	48	98	182	290	570	1,010	1,560	1,950
	10	19	50	103	193	312	600	1,070	1,650	2,060

How to Use the Table

It will be noted that the pressure drop is given in inches water gauge, and as the boiler pressure is usually registered in lb. per sq. in., the following procedure is recommended. First determine the length of piping to the most remote radiator; then, assuming that a pressure of ½ lb. per sq. in. is required at the radiator, the permissible drop will be ½ lb. less than the boiler pressure.

To express the pressure in lb. per sq. in. in terms of inches of water column, multiply by 27·73.

Supposing the permissible drop is 1½ lb. and the length of a particular steam main 200 ft. Then the drop in inches w.g. per 10 ft. will be

$$\frac{1\frac{1}{2} \times 27{\cdot}73 \times 10}{200} = 2{\cdot}08.$$

If the pipe is required to carry, say, 100,000 B.Th.U., reference to the Table shows that a 1½-in. diameter pipe will be needed.

THE DRAINAGE OF BUILDINGS

PART V.—THE DRAINAGE OF BASEMENTS AND SUB-BASEMENTS

IN the drainage of large buildings situated in towns, such as business premises, hospitals, public offices, cinemas, and so forth, conditions may arise to which the ordinary methods of practice will not apply. Such cases need special consideration, and the economy and efficiency of the work are dependent to a marked degree on the experience and ability of the engineer.

Interior Drainage Problems in Large Town Buildings

It may be that the whole site is occupied by the building, without any interior open area, yard, or passage, as shown in Fig. 1, and the basement or sub-basement may be at such a level that the sewage cannot be carried to the public sewer by gravitation, as shown in Fig. 2. The conditions may, therefore, be such that the whole system of drains must of necessity come within the building, and that special means must be adopted for dealing with that part of the sewage which will not gravitate to the sewer. Further, there are cases in which the drains have been laid at such a level that back flooding from the sewer occurs when the sewer is surcharged, as indicated in Fig. 3.

It will generally be found that some, at least, of the soil pipes, waste down pipes, and rain-water pipes exist on the exterior walls, as shown in Figs. 4 and 5, outside the building, where the building abuts on to the road without any area or forecourt. These pipes have to be connected to the system of drains within the building, whence a single connection is carried to the sewer.

It is not permissible under ordinary circumstances to lay private branch drains under the public footway or roadway. It may, however, happen occasionally that there are two or three systems of drains inside a large building, each of which has a separate connection to the sewer. This is very likely to be the case where several buildings, which were originally separate, have been connected in order to form one large business premises.

Down pipes, other than those already mentioned, existing inside the building, will necessarily have to be connected to the interior drainage system.

The above remarks refer chiefly to existing buildings where re-drainage

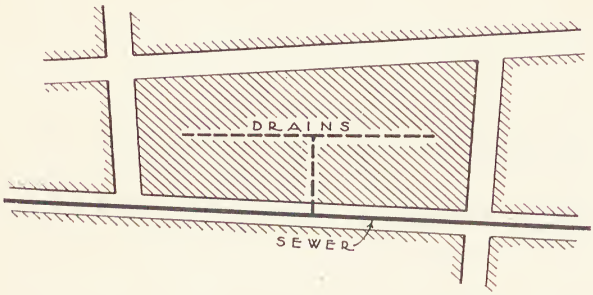


Fig. 1.—PLAN OF BUILDING ON ISLAND SITE WITH NO INTERNAL AREAS

Note drainage system must of necessity be inside building.

is necessary, but the same problems are encountered in the case of new buildings, where it is often necessary to have two or more systems of drains, and where interior drainage work cannot be avoided.

Different Methods of Treatment of Interior Drainage Work

There are several possibilities, each of which requires different treatment. Sometimes all sanitary fittings, including w.c.s, slop sinks, baths, lavatory basins, sinks, and gullies, exist at or above ground-floor level, and the basements or cellars contain no gullies or sanitary fittings, as shown in Fig. 6. In such cases, it may be possible and convenient to connect all sanitary fittings to an iron drainage system constructed above the basement level, consisting of coated cast-iron pipes of the same quality as those used for underground work, with inspection hatch-box manholes at all junctions, changes of direction or

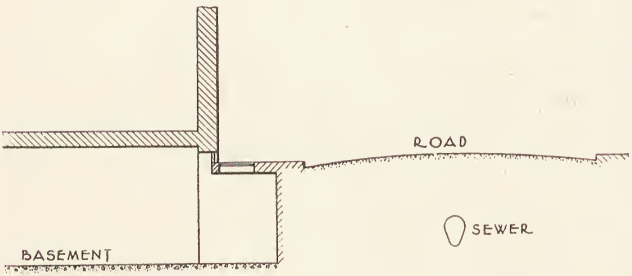


Fig. 2.—SECTION OF BUILDING WITH BASEMENT BELOW SEWER LEVEL

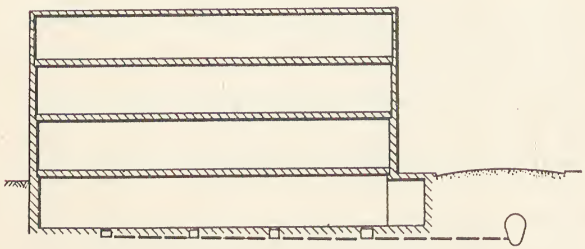


Fig. 3.—SECTION SHOWING POSSIBILITY OF BACK FLOODING
Water may rise in sewer above the basement-floor level.

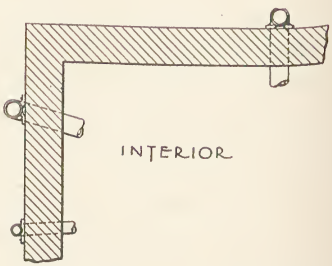


Fig. 4.—PIPES ON EXTERIOR OF WALLS

gradient, and with a special cast-iron interceptor chamber (as shown in Fig. 6A) on the sewer connection.

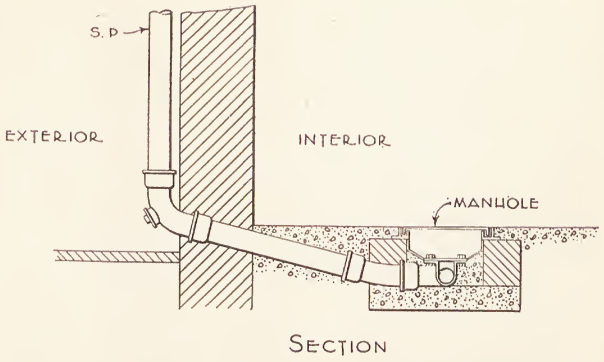


Fig. 5.—PIPE ON EXTERIOR WALL CONNECTED TO INTERIOR DRAINAGE SYSTEM

Use of Sealed Gullies for Waste inside Buildings

When the drains are inside the building, all baths, lavatory basins, sinks, etc., must be made to discharge through waste pipes into gullies which have airtight covers. These covers must be securely bolted down on seatings, so as to be both airtight and watertight. Each gully must have a separate vent-pipe of large diameter carried up to a safe place above the building. The arrangement is shown in Fig. 7.

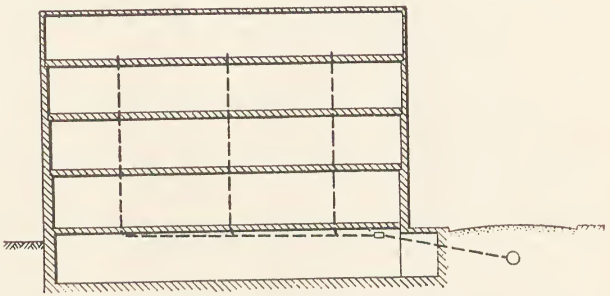


Fig. 6.—SECTION SHOWING GRAVITY SYSTEM
Note drains are above basement level.

In order to explain the nature of the sealed gully and the reason for efficient ventilation by means of a pipe, it is necessary to explain the reason why an open-air disconnection is required between any waste pipe and the gully into which it discharges, and how this demand for an open-air disconnection came to be made originally.

Waste Water Drainage

Sixty years ago, or before that time, sinks in the house were commonly connected directly to the drain. It was common practice to

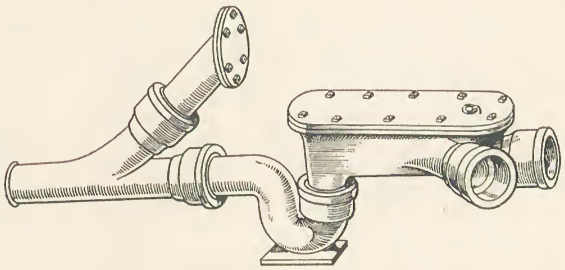


Fig. 6A.—IRON INTERCEPTOR MANHOLE

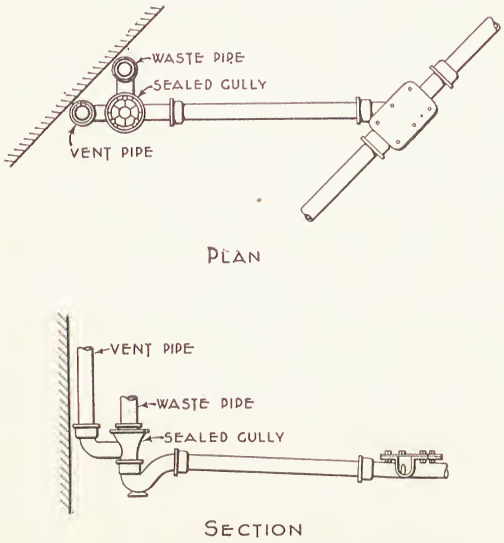
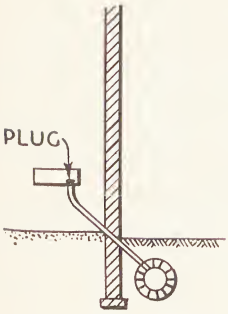


Fig. 7.—SEALED GULLY, VENT-PIPE, AND CONNECTION TO DRAIN

have a large waste pipe, say 2 in. in diameter, carried from the sink into the drain, and a plug was provided at the outgo of the sink which was the only protection against the ventilation of the drain into the house. This was one of the most fruitful causes of trouble and illness; the arrangement is shown in Fig. 9. In order to overcome this difficulty, the sink was provided with a bell trap (shown in Fig. 8). The bell could be lifted off when the sink was flushed, at which times the trap became inoperative, and it was common experience to find that the lifting of the trap admitted drain gas into the house in a very unpleasant manner. Further, owing to carelessness, the trap was very often allowed to remain open.

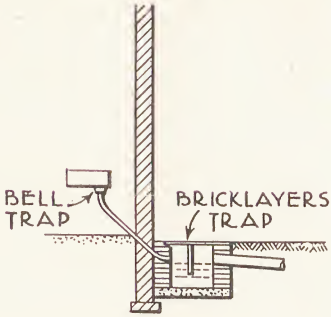
As a further improvement, the waste pipe was connected to an intercepting trap of primitive construction situated outside the house. This trap consisted of a small brick pit, at the head of the drain, which stood full of liquid up to the level of the drain outlet, but the passage of gas from the drain was intercepted by a vertical slab of stone which dipped into the liquid, as shown in Fig. 10. A trap of this kind was not self-cleansing, and as a consequence large quantities of grease and objectionable matter accumulated, causing the pit to become very foul, with a consequence that bad air was still drawn into the house when the bell trap was lifted. It will be observed that this trap had a stone cover. When such traps were cleaned, it was often found that spoons, forks, knives, etc., had passed down the waste pipe and had been intercepted. It was probably for this reason that the waste pipe was first made to discharge above an open grid, which was fixed over this trap as shown in Fig. 11. It was soon appreciated that a very great improvement had been effected by this arrangement, seeing that the waste pipe was no longer connected directly to the foul pit, but discharged into the open air, and in order to make the arrangement still safer, it was

Fig. 8.—BELL TRAP OVER SINK WASTE—AN OBSOLETE METHOD



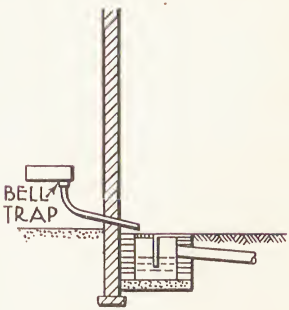
OLD SINK WITHOUT TRAP CONNECTED DIRECTLY TO DRAIN

Fig. 9.



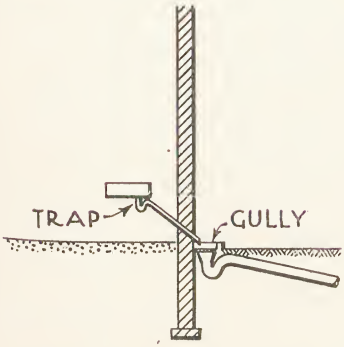
WASTE PIPE WITH BELL TRAP CONNECTED TO BRICKLAYERS TRAP

Fig. 10.



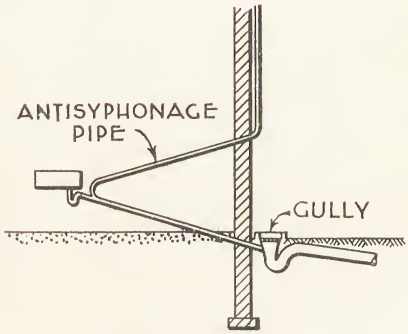
WASTE PIPE WITH BELL TRAP & OPEN AIR DISCONNECTION

Fig. 11.



WASTE PIPE PROPERLY TRAPPED & DISCHARGING OVER GULLY

Fig. 12.



WASTE PIPE PROPERLY TRAPPED & DISCHARGING UNDER GULLY GRID

Fig. 13.

Figs. 9 *to* 13.—HOW WASTE WATER DRAINAGE HAS DEVELOPED

made to discharge into a channel 2 or 3 ft. away from the pit, which still remained foul.

The Invention of the Siphon Trap

A very great improvement was effected by the invention of the siphon trap, which not only was applied to the sink waste pipe, but also replaced the old-fashioned bricklayer's trap. The arrangement is shown in Fig. 12. A gully of this type is more or less self-cleansing, and, in any case, it cannot retain a large quantity of foul matter and can be kept perfectly clean with very moderate attention. A waste pipe could be made to discharge with safety immediately above the grid, but so strong was the feeling against any possible connection with a gully, owing to

the tragic experiences dating from the times of a direct connection between the waste pipe and a foul drain or trap, that many authorities to this day still demand that the waste pipe shall discharge into a channel 2 or 3 ft. from the gully. This has been proved to be unnecessary, and it is now common practice to connect the waste pipe below the grid of the gully but above the water line of the trap, because the trap is not foul, and because the fresh air has free access to the upper part of the gully.

When the gully receiving such a waste pipe, or perhaps more than one waste pipe, must of necessity be placed inside a building, clearly it would be wrong to allow the contaminated air issuing from the waste pipes to escape from the gully grid, and the gully top must, therefore, be made airtight, the cover taking the place of the grid, but it is still necessary to provide the fresh-air disconnection, and this is done by means of a vent-pipe, as shown in Fig. 7.

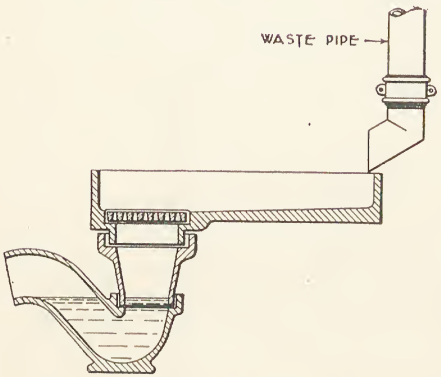


Fig. 14.—THE CHANNEL WAS REQUIRED ORIGINALLY BECAUSE THE GULLY WAS NOT SELF-CLEANSING

The Vent-pipe for Waste Gully

This ventilation is required, in the first place, in order to prevent an air lock, because a trapped waste pipe discharging into an unventilated space above the gully trap might cause the air to be compressed and an air lock to occur in the waste pipe. Ample ventilation may be provided by means of a vent-pipe of large diameter, connected to the gully above the trap-water level, and carried to a safe point above the building. A vent-pipe similar to that of a soil pipe, or of a main down pipe serving a number of baths and sinks, must be provided. It should be clearly understood that the reason why the gully situated inside a building, receiving discharges from waste pipes, must be provided with a sealed airtight cover, is because waste pipes become coated with grease and soap and foul matter on the interior surfaces, which become septic, and each flush of water—particularly warm water—coming down displaces a certain volume of contaminated air of dangerous quality, which would escape into the building if the gully had an open grid. As an example of possibilities, if the waste pipe from a kitchen sink were connected to an open gully inside a building, there would be a strong smell of cabbage water every time the water in which such vegetables had been boiled passed out of the sink into the waste pipe and gully.

Where a gully is used for other purposes, such, for instance, as for the

reception of floor washings in a basement, the same objections do not arise, although there may be other reasons why it is undesirable to place open gullies inside a building, the chief reason being that unless they are placed in such positions that they will receive frequent flushing, and unless they are carefully attended to, the traps may become unsealed owing to evaporation, and the drains may thus be ventilated into the building. However, with proper arrangement and maintenance, there is no greater objection to an open gully inside a building, provided it does not receive the discharge from waste pipes, than there is to the existence of the open traps of the ordinary w.c.s which exist inside all inhabited buildings.

Inspection Boxes

The drains from gullies and the connections to soil pipes, w.c.s, and slop sinks, etc., must be carried to iron inspection hatch-boxes on the drains. The arrangement is shown in Figs. 5 and 7.

RAIN-WATER DRAINAGE

Where rain-water must be taken into the drainage system by means of down pipes descending through the building, it is most important that the pipes shall be properly disconnected from the drains, and, for this reason, they are sometimes connected to the trapped gullies with sealed covers which receive the flow of water from waste pipes, with the idea that there may be no risk of the gully trap becoming unsealed by evaporation. Great attention must, however, be given to the arrangement for reasons stated below.

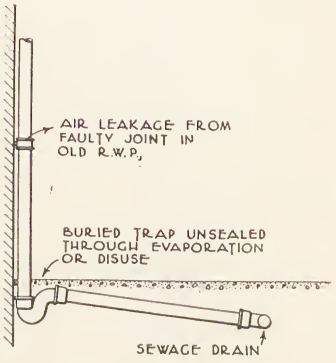


Fig. 15.—AN IMPERFECT ARRANGEMENT FOR RAIN-WATER DRAINAGE—SOMETIMES FOUND IN OLD WORK

Should Rain-water Pipes be Connected to Gully inside Building?

In many cases, on old work, it will be found that the rain-water down pipes are of poor quality, with unsound joints, and where they descend inside the building they are sometimes connected to traps which are generally hidden under the pavement of the basement, as shown in Fig. 15. This arrangement is very imperfect, for the reason that if the trap of the gully becomes unsealed by evaporation, the rain-water down pipe will act as a drain ventilator and may admit drain air into the house through the leaky joints, or allow it to escape in undesirable positions near the eaves of the roof. It is also probable that such traps will become blocked, and if they are inaccessible for cleaning, there is the likelihood that sooner or later there will be great trouble from an outflow of rain-water at ground level or from leakages in the pipe above ground

level. It may be urged that a trap inside the house under the pavement of the basement is not likely to become unsealed by evaporation, but the possibility undoubtedly exists. There is also another danger, which is always present with gullies inside a building, namely, that owing to structural alterations or to changed conditions, a down pipe may cease to be operative, and a dead down pipe and dried-up gully may ventilate the drains into the building. The present writer has encountered such cases in ordinary practice.

If the rain-water down pipe is connected into a ventilated sealed gully, receiving ordinary wastes, the possibility of a trap being unsealed by evaporation is overcome, but it is very important that the rain-water down pipe inside a building should be of strong quality, with airtight joints, for the reason that, although no drain air will enter the pipe, the bad air from the waste pipe connected to the gully may be drawn into the rain-water down pipe. Further, it is very necessary to observe whether the top of the rain-water pipe is situated in such a position that such ventilation would be harmless.

It cannot be said that the connection of a rain-water pipe to a gully of any kind inside the building is altogether desirable, and in new buildings it ought to be avoided.

Separate Rain-water System

It is undoubtedly better practice to connect all rain-water down pipes to a separate system of drains, and to carry the main rain-water drain to a separate interceptor manhole which can be connected with safety to the sewage drains. Such an interceptor, situated in a proper chamber having a trap with a deep seal, will not evaporate. At the first glance the idea of a separate system may appear to involve extra expense, but this is not necessarily so. Under such circumstances, no gullies will be required : this alone is an important saving, and again there will not be the same need that the rain-water down pipes shall be of special quality with airtight joints, and there will be no complicated connections to sealed gullies or to the drainage-system manholes.

Gravitation Drain in Basement

It will often be found that the basement-floor level is well above the sewer level, making a gravitation connection possible, as shown in Fig. 16. In such a case, drains are generally laid below the basement floor and carried to an interceptor chamber in the usual manner, all soil pipes and down pipes being connected to the system as described above. In old work the fresh-air inlet to the interceptor manhole was generally arranged very badly ; sometimes a pipe was carried up to just above pavement level on the outside wall, in a position where an outlet of drain air, such as may always occur from an inlet ventilator, may be very objectionable ; elsewhere, the air inlet was sometimes actually placed

inside the basement, which was, of course, both wrong and dangerous. It is for this reason that the by-laws of the London County Council require that every drain-ventilating pipe "shall be carried up vertically to such height and position as to prevent any nuisance or injury or danger to health arising from the emission of foul air from such pipe," which means that in most cases the fresh-air inlet pipe to any interceptor manhole which is constructed inside the building will have to be carried up, like the soil vent-pipe, to a safe place above the roof of the building.

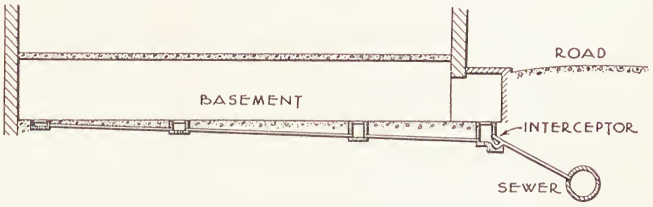


Fig. 16.—GRAVITATION DRAIN IN BASEMENT

Drain Suspended between Ground-floor and Basement Levels

If there are no sanitary fittings or gullies below ground-floor level, it may be better and more economical to keep all drains, gullies, etc., above the basement level, especially in the case where a proper fall in the connecting drain to the sewer would not be possible from basement level. Such an arrangement is indicated in Figs. 6 and 17. The whole system of drains might in this case be suspended from the floor girders on hangers. These hangers must be of sufficient strength. A good arrangement is shown in Fig. 18. Special hangers of this kind can be procured from manufacturers. The brackets shown in Fig. 18 and in Fig. 20 are also used for supporting pipes, being built into the wall, and the roller shown in Fig. 18 allows movement in the case of a long pipe-line where expansion and contraction are expected. The arrangement shown in Fig. 19 is sometimes adopted in the case of wooden beams, but, speaking generally, such beams are unsuitable for the support of pipes. Where the conditions are suitable, the pipes may be supported on brick or concrete piers.

The practice of arranging drains above ground level where required is in perfect accordance with good practice, and may be compared with the arrangement of soil pipes and their branches inside buildings. Drains constructed in this manner above the basement-floor level, where they are visible and accessible, are really safer than

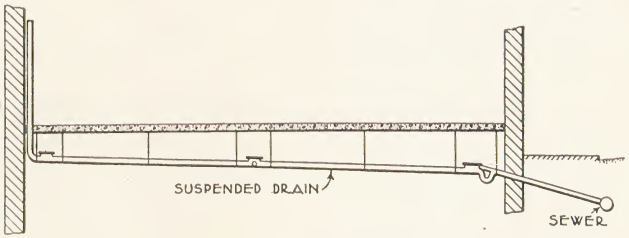


Fig. 17.—DRAIN SUSPENDED BETWEEN GROUND-FLOOR AND BASEMENT LEVEL

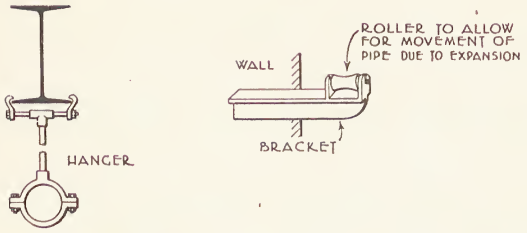


Fig. 18.—METHODS OF SUPPORTING DRAIN PIPES ABOVE GROUND

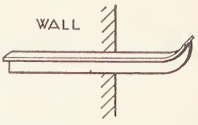


Fig. 20.—WALL BRACKET FOR PIPE

underground drains, because if any leakage occurs it will at once be apparent and will be remedied.

Allowing for Expansion in Long Lengths of Pipe

In very large schemes, long lengths of iron pipe may sometimes occur, in which case, the effects of expansion and contraction have to be considered. This is a matter which can be calculated, because the amount of expansion which will take place in a given length of cast-iron pipe owing to a definite change of temperature is known. Expansion joints, consisting of a gland and stuffing-box, can be inserted on the line of drain. Such joints as that shown in Fig. 22 are sometimes used. It may also be suggested that the Stanton-Wilson joint shown in Fig. 23, or the mechanical lead joint shown in Fig. 24, might be used with advantage under such conditions. With the ordinary lead joint, the movement of the pipes on a long line will cause the caulked lead to come out of the socket, whereas this is impossible with the joints illustrated above. It is to be remembered that very hot water may be discharged into drains, particularly in the case of large restaurants or other places where a great deal of boiling water is used for washing plates and dishes. Seeing that the temperature of

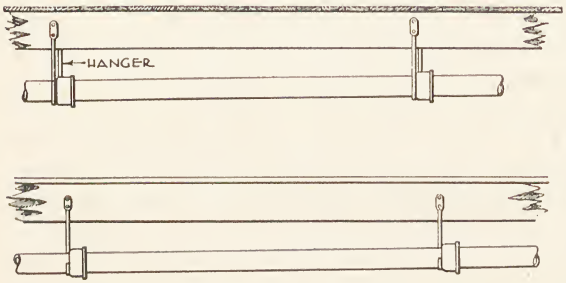


Fig. 19.—NOT A SATISFACTORY METHOD FOR SUPPORTING DRAIN PIPES

Showing pipe hangers attached to timber beams.

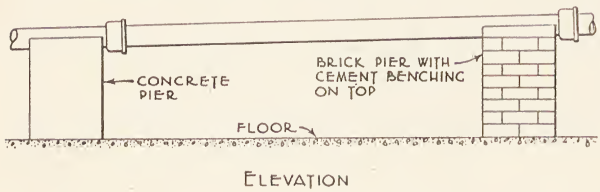


Fig. 21.—PIPES MAY BE SUPPORTED ON BRICK OR CONCRETE PIERS AS SHOWN

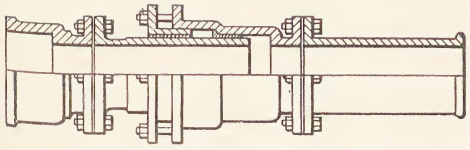


Fig. 22.—EXPANSION JOINT

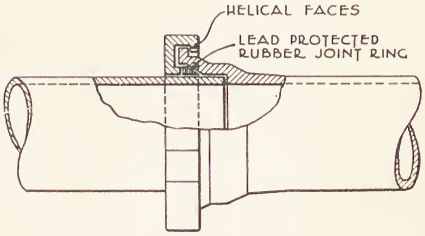


Fig. 23.—THE STANTON-WILSON PATENT FLEXIBLE PIPE JOINT

boiling water is 212° F., and the temperature of the drains in a basement may easily fall to 40° or even considerably lower, it is evident that wide ranges of temperature are possible. The expansion on a 200-ft. length of cast-iron pipe, with a change of temperature of only 50°, would be about $\frac{3}{4}$ in.; thus it is clear that with a high range of temperature and a long length of pipe above ground, the contraction and expansion may be such as to upset the supports of pipes and to cause caulked lead to work out of the sockets. In order to allow movement, the pipes are supported on rollers. Where they rest on brick piers a sheet of lead is sometimes provided as a seating, in order to allow movement, but even this precaution has been found to be insufficient upon a very long length of pipe of large diameter. It is possible to calculate the amount of expansion as follows :—

Cast iron will expand $\frac{1}{162,000}$ of its length for every degree F. rise in temperature ; thus :—

$$\frac{\text{length of pipe line}}{162,000} \times \text{rise in temperature in degrees F.} = \text{amount of expansion}$$

LIFTING AND PUMPING SEWAGE FROM BASEMENTS

The sewage of buildings can be lifted by means of the automatic electric pump, the ejector, or the sewage lift.

Arrangement of Ejector in Basement

The ejector consists of a vessel which receives the sewage at a low level, and from which the sewage is expelled by means of compressed air and forced up a rising main to discharge into a gravitation drain at a higher level. It can be obtained from makers who also supply a small, electrically driven compressor, and an air container for the storage of compressed air. The ejector can be placed inside the building, is entirely automatic in working, and needs very little

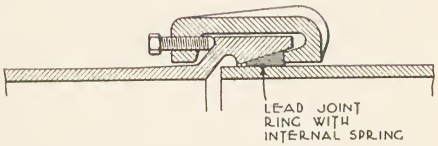


Fig. 24.—STANTON MECHANICAL LEAD PIPE JOINT

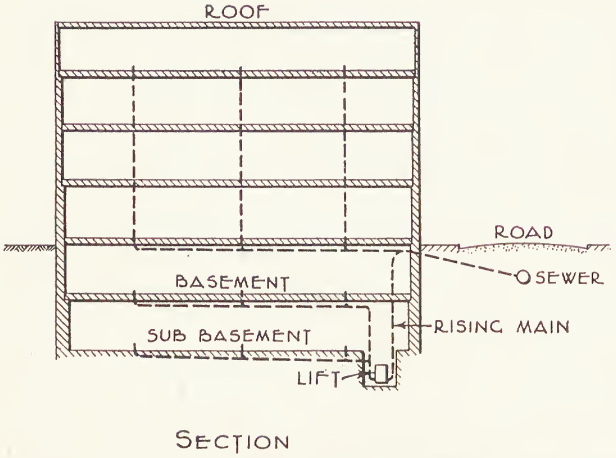


Fig. 25.—GRAVITATION AND LIFTING SYSTEMS IN BUILDING WHERE SEWER LEVEL DOES NOT PERMIT DRAINAGE OF BASEMENT AND SUB-BASEMENT BY GRAVITATION

attention. The arrangement is shown in Figs. 25, 26, and 27. The vessel into which the sewage flows contains a float, and the inlet and the outlet pipes are provided with flap-valves. The compressed-air pipe is connected at the top of this container, and the compressed air is admitted as soon as the container is full of sewage, because the rise of the float opens a valve on the air main. The sewage is expelled from the vessel in this manner, and flows through the rising main to any level required. When the sewage has been expelled, the fall of the float closes the valve through which compressed air is admitted, and the process is repeated. This method of sewage-lifting has been in use both on a small scale and on a very large scale for very many years, and for ease of working and continuity of operation without trouble is to be preferred to other methods. One very great advantage is that all solid matters are lifted. There is no screening or chokage, and the action is entirely automatic.

Where electric current is not available, the compressor can be run by means of a small oil engine. This does not mean that the oil engine is in continuous operation; it is generally run for perhaps an hour once a day, and the compressed air required for the day's working is stored in a separate air container. The amount of compressed air required is, of course, dependent upon the quantity of sewage to be raised.

Inspection Chamber at Inlet of Ejector

As will be seen in Fig. 26, a small inspection chamber is constructed at the inlet of the ejector so as to allow a small amount of storage. This chamber should be constructed in the same manner as an ordinary manhole, with channels and benching, and it must be provided with a vent-pipe in the same way as an interceptor manhole. It is, however, necessary to make the benching at a steeper angle than is usual in an ordinary manhole, say 45° or even 60°, as it may be quite a frequent occurrence for the sewage to collect, and every precaution should be taken to ensure that everything drains away into the ejector and that nothing

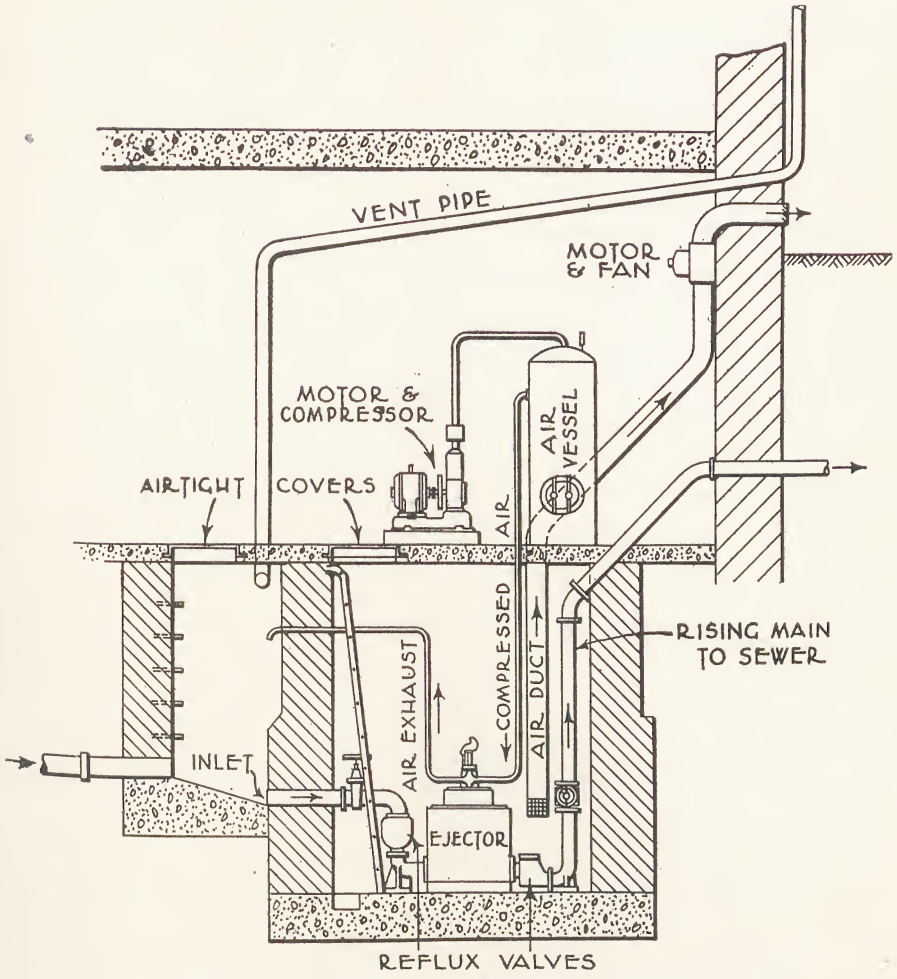


Fig. 26.—ARRANGEMENT OF EJECTOR IN BASEMENT

is left to decompose in the manhole. If possible, the main channel should have a sharp fall—of, say, 4 or 6 in.—from the incoming drain to the pipe leading to the ejector. In normal working, this will prevent the sewage, which may have to be stored while the ejector is functioning, from flooding the drain, there being sufficient storage in the manhole. When the ejector is fixed in a building in a pit, this pit ought to be provided with an airtight cover, and the pit should be properly ventilated to the open air. It is obvious that sewage will be exposed to the air in the case of repairs or valve cleaning, and it would be quite wrong to allow any smell of this kind to enter the house. Also there is danger to men entering an unventilated ejector chamber.

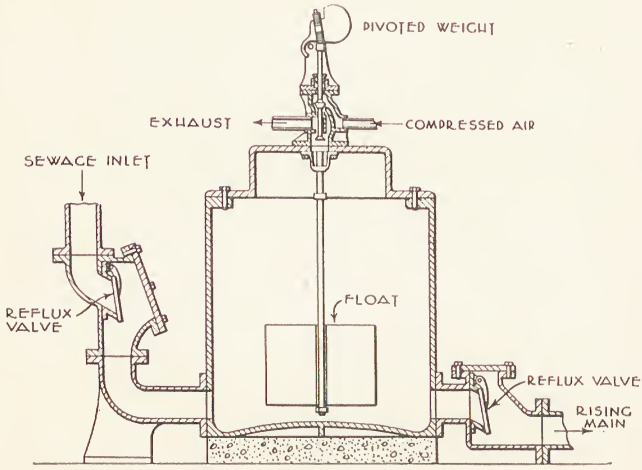


Fig. 27.—EJECTOR FOR LIFTING SEWAGE

Compressed air is supplied by a small compressor driven by an oil or petrol engine, or by an electric motor where current is available. The compressed air is stored in a special cylinder at a pressure which is considerably higher than that which is necessary for lifting the sewage. It is admitted to the ejector as required through a pressure-reducing valve, and this permits the use of a small air-storage cylinder in which a high pressure is maintained. In some plants, the loss of pressure in the air receiver is made to operate an electric switch which starts the motor automatically, in which case the air receiver can be of still smaller capacity. This method of automatic control is satisfactory where the compressor is electrically driven, but it is less certain where a petrol or oil engine is used, although it may be fairly effective. Where several ejectors are required, they are supplied with the air from one central station, air mains running to each.

Automatic Pumps for Pumping Sewage from Basements

Speaking generally, this is the cheapest method of raising sewage, but a very small pump requires very much more attention than an ejector or than the automatic sewage lift later described. Small pumps, such as may be necessary in moderate-sized buildings, require a certain amount of regular attention in case of stoppage or breakdown, although they may run for a very long time without any attention. It is necessary, where a pump is employed, to provide a tank, which must hold a certain quantity of sewage from which the pump can draw. The pumps used are of the centrifugal type, specially designed to prevent clogging. Some of these are of such design that they will cut up and disintegrate the solid matters in sewage, but even these may be choked by rags, especially in the smaller sizes. If possible the electric motor driving the pump is kept above the ground level; thus the pumps generally have a vertical spindle with a motor placed above. In some cases the pump is actually immersed in the collecting tank, being suspended from the roof above and driven by means of a vertical spindle. The whole pump can be lifted for

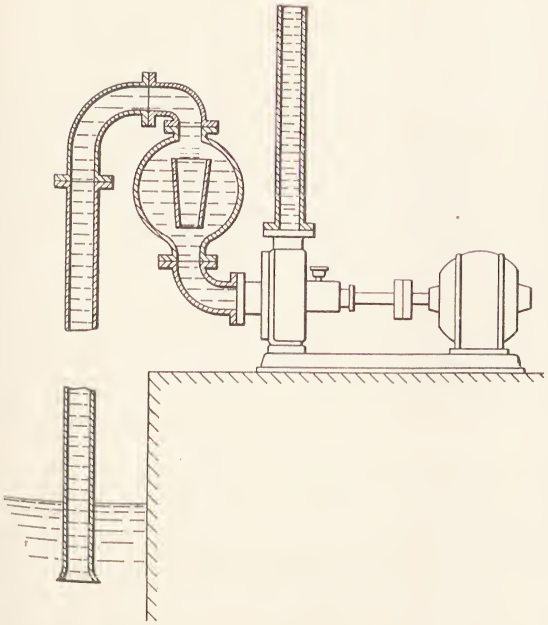


Fig. 28.—THE SEABORNE INTERCEPTOR

Appliance used for keeping centrifugal pump primed in cellar drainage.

attention when necessary. This avoids the construction of a separate chamber for the pumps. The pumps must always be placed at a level below that of the liquid to be lifted, because otherwise they would have to be primed each time they were started. The current is switched on to the motor by means of a float, thus the pump comes into operation as soon as the tank is filled above a certain level.

THE SEWAGE LIFT

The sewage lift is an apparatus in which the compression of air required in order to raise the sewage from an ejector is obtained by utilisation of sewage or water flowing from a higher level. In a building it is not at all probable that the sewage of the higher level could be utilised for this purpose, partly for the reason that the volume would probably be insufficient, and partly owing to the practical impossibility of storing sewage at the high level in a building without creating a very insanitary condition. It may, therefore, be assumed that the only way of operating a sewage lift in a building would be by utilisation of clean water. Seeing that the quantity of water required for sewage lifting with this appliance is equal to double the quantity of sewage to be lifted, the cost of the water required would generally make the scheme prohibitive. On the other hand, there are cases where the quantity of sewage to be lifted is very small, and where the volume of water available is unrestricted.

Arrangement of Sewage-lift Equipment

With the sewage lift a tank is arranged at a high level, and water is supplied to this tank through a ball valve. A flushing siphon is fixed in the tank, and discharges the contents into a pipe so that water compresses the air and displaces it. This pipe is connected to a cylinder from which an air pipe runs to the forcing chamber, or ejector, thereby

causing the sewage to be expelled and to be raised to a higher level through a rising main.

The ejector, or forcing chamber, has an inlet and outlet provided with flap-valves, and it fills up with sewage from the low level as described in the case of the sewage ejector first mentioned. The water which is used flows into the high-level drain. The air pipe is taken off the top of the air cylinder and rises to a greater height than that to which the sewage has to be lifted, and is connected into the top of the forcing cylinder, namely, the ejector. The flush tank at the top is of sufficient capacity to more than fill the air cylinder.

A siphon pipe is connected to the air chamber, which reaches nearly to the bottom, and is also carried up to a height greater than that to which the sewage has to be raised, but slightly less than that of the air pipe. From this point it descends and is connected to the high-level drain.

When the siphon discharges, water is forced up this pipe until the head is sufficient to produce pressure to raise the sewage, but the water does not rise up the air pipe until all the air in the cylinder has been used. The water discharged from the flushing tank, being more than sufficient to fill the air cylinder, rises in the siphon pipe until it gets over the bend at the top and begins to run to the high-level drain. When once started this goes on flowing until all the water has been siphoned out of the air cylinder. The air pipe, being carried up to a greater height, no water passes through it into the forcing chamber.

Practically all the water is siphoned out as stated above, the air being admitted through a vent in the top of the flush pipe, and a free vent being thereby provided for air displaced in the forcing chamber by the incoming sewage ; that is to say, it will pass up the air pipe through the air cylinder and up the flush pipe to the vent at the top ; it can also pass through the siphon pipe.

The apparatus is set in action, when the forcing chamber is full, by means of a small float which opens a valve on an air pipe connected to the dome of the flushing siphon. When the air is released from this dome the flushing siphon comes into operation. The sewage lift can be used in a building under favourable circumstances, but it is generally used in much larger schemes for raising the sewage from a low-lying district, the sewage from an upper district being used for filling the flushing tank. The flushing chamber and air cylinder may be situated, if necessary, at a considerable distance from the forcing chamber.

SMALL AUTOMATIC PUMPS FOR LIFTING LAND WATER FROM FOUNDATIONS

It is sometimes necessary to pump the land water, which is collected in agricultural drains laid under a building and drained to a sump. This has to be done when it is impossible to carry the water safely to the drains or sewers by gravitation. Such pumps may be very small, even with a delivery pipe of only ½-in. diameter if the quantity to be discharged is very little, and if there is no chance of any solid matter having to be lifted. They are usually worked by means of a small electric motor put into operation by means of a float. In very small sizes the gear-wheel type of pump can be used, but from about 1 in. in diameter upwards the centrifugal type of pump is more common.

Priming Arrangements

In most cases the small pumps are placed above the level of the water to be raised, and where this is the case special priming arrangements are often required. The suction pipe is provided with a foot valve, but such valves are liable to stick, in which case the pump will lose its water and be unable to deliver anything when started, which will probably result in the basement being flooded before it is discovered. One of these self-priming arrangements is known as the "Seaborne interceptor"; it consists of a small container which is fixed on the suction pipe of the pump, the pipe and container being carried above the pump. When the pump stops working the suction pipe empties, and this leaves the container full of water, and as it is above the pump the pump remains charged with water. When the pump starts again it uses this water, and the air in the suction pipe takes its place until more water is drawn into the container through the suction pipe. The container is made to hold more water than the suction pipe, thus it may be half empty before more water begins to enter, but the pump still remains charged. There is a funnel-shaped pipe in the middle of the container, through which the inflowing water passes; this acts as an injector, so that the air drawn out of the suction pipe mixes with the water and can be passed through the pump. The arrangement is shown in Fig. 28.

Duplicate Installation Required

The removal of land water under the foundations of basements, especially in older buildings where watertight construction has not been adopted, may be a matter of very great importance, but under the worst conditions it can be drained to an underground tank of sufficient capacity, whence it may be pumped by automatic appliances and discharged into the drains with safety. It is, however, most important that the plant should be in duplicate, and that it should be carefully attended to at all times.

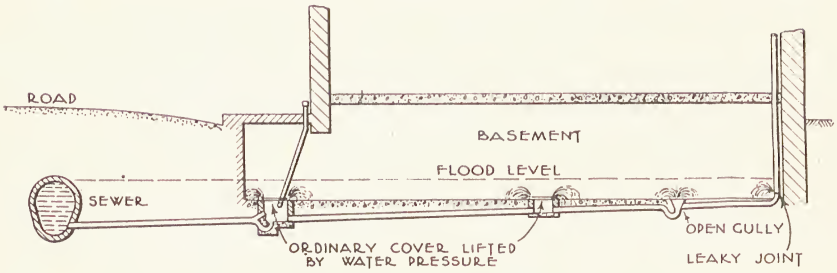


Fig. 29.—Basement flooded owing to surcharged sewer—an actual case
Note the surcharge was due to storm water in times of heavy rainfall.

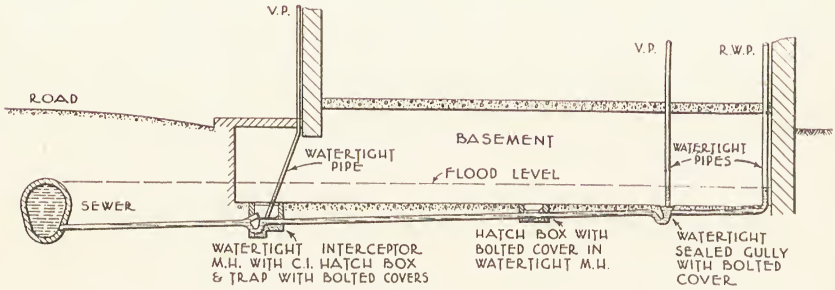


Fig. 30.—Prevention of basement flooding

Use of Automatic Ejector

Where the quantity of land water to be lifted from the basement or foundations of a building is not excessive, it is possible to install a very small automatic ejector which is operated by means of a float-controlled valve, the pressure from the water in the house mains being utilised for the purpose. This appliance can be fixed in a small sump, it is cheap, and is very useful where the quantity of water to be raised is small. It sometimes happens that a very small continuous inflow may accumulate and cause great trouble, but yet can be dealt with satisfactorily by lifting a very small quantity occasionally. For dealing with larger quantities, the volume of water required from the house system in order to operate the appliance would generally be too great to make it an economical possibility.

Electric Pumps

Very small electric pumps worked by motors with power as low as $\frac{1}{15}$ h.p. are also used for cellar drainage.

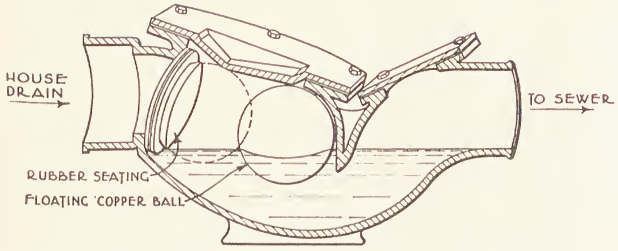


Fig. 31.—AUTOMATIC VALVE FOR PREVENTING BACK FLOW FROM SEWER INTO HOUSE DRAINS

AVOIDING BACK FLOODING FROM SEWERS

The possibility of back flooding from a sewer into house drains has a very important bearing on the drainage of basements. Two examples taken from the experience of the present writer are given below.

An Example

In the first case, the basement drains had a reasonable fall to the sewer, and if the sewer had been capable of carrying its full flow in time of heavy rainfall, flooding would not have occurred. However, this was not the case, and in times of storm, water headed up from the sewer with the result that a serious backflow occurred, which flooded the basement showrooms of a very large business establishment. Fig. 29 indicates this condition. On these drains the manhole covers were of a double-seal type, but were not bolted down, and consequently they could be lifted by water pressure coming on the under side. Water also entered the building through open gullies and at places where defective joints occurred in down pipes. At the end of the main drain where it entered the sewer a flap-valve existed, and flooding occurred because this valve was held open by sewage matter.

In order to prevent flooding, the following steps were taken :—

(1) The flap-valve was cleaned and set in working order. This prevented flooding at first, but ultimately the flooding recurred.

(2) The drains were tested and were carefully repaired, so that no leakage could occur ; cast-iron hatch-box manholes with covers bolted down were installed at every inspection chamber and, as an additional safeguard, bolted-down covers were fixed in the place of the old covers on the pits. All gullies in the basement were provided with sealed covers and were properly ventilated.

(3) All rain-water down pipes were made absolutely sound and water-tight where they passed through the basement, and all soil pipes, waste pipes, and vent-pipes were also made absolutely sound. Special attention was given in each case to the joint between the pipe and the drain to which it was connected.

This work was very difficult, as it had to be carried out in business showrooms with as little disturbance as possible. It involved relaying the bulk of the system in cast-iron pipes, and the renewal of many down pipes, but the cost of the work was small in comparison with the advan-

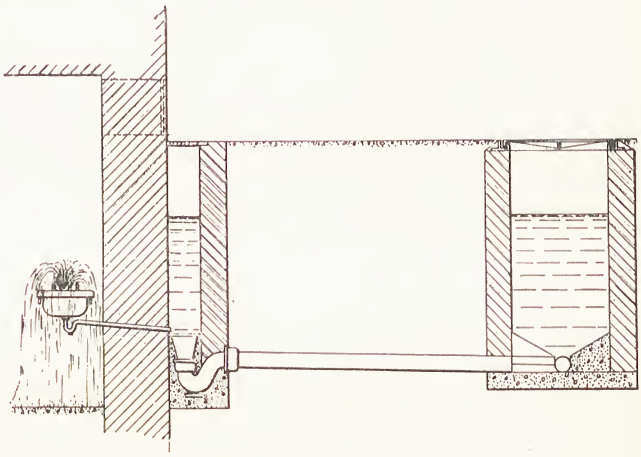


Fig. 32 (*right*).—BACK FLOODING

Actual example occurring in the basement of a cinema where new drains were connected to a sewer which had its outfall in tidal water. At times of high tides, the sea-water flowed back into the sewer, causing the sewage to rise to such a level that it overflowed on to the floor from the lavatory basins, as shown.

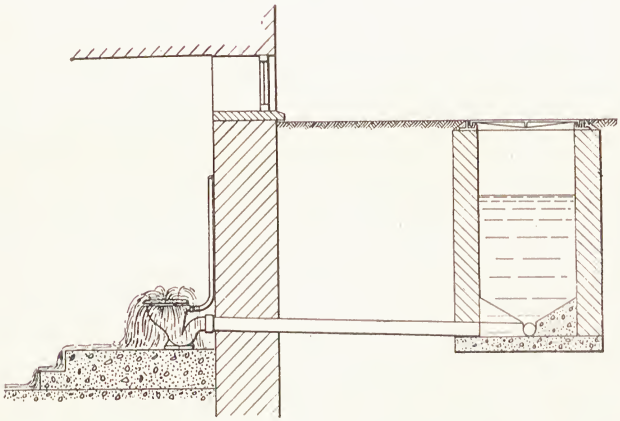


Fig. 33 (*left*).—BACK FLOODING

The same instance of back flooding as described under Fig. 32, showing how the water overflowed from the w.c.s.

tages obtained in the exclusion of the flood water. It may be added that over a period of many years there has been no recurrence of flooding. Fig. 30 indicates the manner in which the drains and down pipes stood full of water considerably above basement-floor level at times when the sewer was surcharged.

Devices to Prevent Back Flooding

In order to prevent back flooding from a surcharged sewer, the flap-valve is moderately effective. Another device is the auto-flooding ball-valve interceptor, shown in Fig. 31. This is an intercepting trap containing a floating copper ball on the upstream side ; any backflow into the drain forces this ball against a rubber seating on the end of the inlet drain pipe. Another device which may have its uses is a gully which

works upon the same principle, in which a rise of liquid in the trap causes the floating ball to close the inlet. Such devices may be very useful under certain conditions, where the absolute exclusion of even a small quantity of water at all times may not be essential, but they do not allow of any discharge of water from the drains while the flood is up, and it is also obvious that any automatic valve of this kind may fail to be absolutely watertight at times, and even small leakage may be very troublesome and even disastrous. Thus, some positive method of exclusion is preferable, such as keeping all sanitary fittings, gullies, and manholes above flood level.

Another Example of Back Flooding

The second example of back flooding is that which occurred in the basement of a cinema, where new drains were connected to a sewer which had its outfall in tidal water. At times of very high tides, the sea-water flowed back into the sewer, causing the sewage to rise to such a level that it overflowed from the basement sanitary fittings. In this basement there were w.c.s; and lavatory basins also existed in dressing-rooms. The drainage system in this case was outside the building, and observation showed that water rose in the manholes above the level of the tops of the basins inside the building. As will be seen in Fig. 32, water heading up in the manhole would rise in the deep gully pit outside and flow up through the basin waste pipe so as to overflow on to the floor. Similarly, as may be seen in Fig. 33, it would overflow from the w.c.s. In this case it was decided to disconnect the drains serving the basement fittings from the main system, and to connect them to an ejector whence the sewage could be lifted so as to discharge into the main drainage system well above flood level, thereby making back flooding an impossibility. The quantity of sewage discharged from the basement fittings was very small, so that the actual output of power required by the ejector was inconsiderable. It would have been equally possible to have installed a small automatic electric pump.

QUESTIONS AND ANSWERS

What treatment is possible when Sanitary Fittings all exist at or above Ground-floor Level, and the basement contains no gullies or sanitary fittings?

It may be possible and convenient to connect all sanitary fittings to an iron drainage system constructed above the basement level, consisting of coated cast-iron pipes of the same quality as those used for underground work, with inspection hatch-box manholes at all junctions, and changes of direction and gradient, and with a special cast-iron interceptor chamber on the sewer connection.

What precautions must be observed when Waste Drains are within the building ?

All baths, lavatory basins, sinks, etc., must be made to discharge through waste pipes into gullies which have airtight covers. The covers must be securely bolted down on their seatings so as to be both airtight and watertight. Each gully must have a separate vent-pipe of large diameter carried up to a safe place above the building.

What were the improvements effected by the invention of the Siphon Trap ?

It replaced the old-fashioned bricklayer's trap by a gully which was more or less self-cleansing, and, in any case, it cannot retain a large quantity of foul matter, and can be kept perfectly clean with very moderate attention. The waste pipe could be made to discharge with safety immediately above the gully grid.

Why is it necessary to provide a Sealed Airtight Cover for a gully receiving discharges from waste pipes inside a building ?

Because waste pipes become coated with septic grease, soap, and foul matter on the interior surfaces, and each flush of water—particularly warm water—coming down displaces a certain volume of contaminated air, which would escape into the building if the gully had an open grid.

Why is it necessary to provide a Vent-pipe for a gully which receives discharges from waste pipes inside a building ?

Ventilation is required in order to prevent an air lock, because a trapped waste pipe discharging into an unventilated space above the gully trap might cause the air to be compressed and an air lock to occur in the waste pipe.

Why should not Rain-water Pipes inside a building be connected to buried gully traps ?

If the trap of the gully becomes unsealed by evaporation, the rain-water pipe will act as a drain ventilator, and may admit drain air into the house through leaky joints, or allow it to escape in undesirable positions near the eaves of the roof. It is also probable that such traps will become blocked, and if they are inaccessible for cleaning there is the possibility that sooner or later there will be an outflow of rain-water at ground level or from leakages in the pipe above ground level. Another danger is that, owing to structural alterations or to changed conditions, the rain-water pipe may cease to be operative, and a dead down pipe and dried-up gully may ventilate the drains into the building.

What is the objection to Rain-water Pipe being connected into a Ventilated Sealed Gully receiving ordinary wastes inside a building ?

Although no drain air will enter the rain-water pipe, the bad air from the waste pipe connected to the gully may be drawn into it, with the possibility of leakage into the building if the pipe is not of special quality, and the joints are not airtight. Further, it is necessary to observe whether the top of the rain-water pipe is situated in such a position that such ventilation would be harmless.

What is the best practice with regard to Rain-water Disposal inside a building ?

Connection of all rain-water pipes to a separate system of drains, and carrying the main rain-water drain to a separate interceptor manhole which can be connected with safety to the sewage drains. Evaporation will not take place from a deep-seal interceptor situated in a proper chamber.

Would a Separate System necessarily involve extra expense ?

No. Under such circumstances no gullies will be required, and there is not the need for the rain-water pipes to be of special quality with airtight joints. There will be no complicated connections to sealed gullies or to drainage system manholes.

How are Drains laid inside a building where the Basement-floor Level is well above the Sewer Level ?

As a gravitation connection is possible, the drains are generally laid below the basement floor and carried to an interceptor chamber in the usual manner. If there are no sanitary fittings or gullies below ground-floor level it may be better and more economical to keep all drains, gullies, etc., above the basement level, by suspending the drains from floor girders or supporting on brick or concrete piers.

HEATING AND VENTILATION

PART IX.—PREPARATION OF ESTIMATES AND SPECIFICATIONS—RUNNING COSTS

AFTER the completion of his calculations and the layout of the proposed installation, the preparation of the estimate will engage the attention of the engineer. In this, much time will be saved if the quantities are set out and priced methodically. There will also be less risk of costly omissions if the items are grouped into sections, and the sections dealt with in the same order as they occur in the specification.

A brief indication of the type and size of each article, and, when necessary, the manufacturer's name, will be found of use at a later date if the contractor is successful in obtaining the order. Although the particular type and make of an article may be clearly understood at the time of estimating, some months *may* elapse before it will be necessary to order the goods, and by then the particular requirements of the customer will have been forgotten.

It is not sufficient, for example, to write down " $1/\frac{3}{4}$-in. valve," without also stating the pattern, finish, or other characteristics. If it is a radiator control valve, it is advisable to include it in the group of items in the section headed " Radiators," so that the reason for its inclusion will be apparent. A sufficient description will probably be: " $1/\frac{3}{4}$-in. Brown's Fig. 249 Ch.Pl. Angle Pat. Valve "—to show that a $\frac{3}{4}$-in. diameter angle-pattern radiator valve in chromium-plated finish, and of Messrs. Brown's Fig. 249 type, is required.

A Typical Estimating Sheet

A typical estimating sheet is shown on pages 425 and 426, from which it will be noted that the sheet is headed with the name of the building, the inquiry number, and the date—which should be that of the day when the estimate is submitted. The estimate is numbered, and a short description of what it is for is given before the actual quantities are commenced.

The numbering of estimates is advisable, because it frequently happens that one or more revisions may have to be submitted before the order is placed, and reference to them at a later date is simplified by this method.

At the end of the quantities of material a total is made to which is added the estimated cost of labour, items for carriage and/or cartage,

TYPICAL ESTIMATING SHEET

Inquiry No. 12,345. *Date*

Name : House at Southend. *Estimate No.* 1.

LOW-PRESSURE HOT-WATER HEATING

	£ s. d.	£ s. d.
Boiler		
1 C.I. boiler (maker's name and pattern) rated at 450,000 B.Th.U.	54 0 0	
1 8-in. diam. smoke bend with cleaning door	10 0	
3 ft. 8-in. diam. smoke pipe	12 6	
1 set stoking tools	17 6	
		56 0 0
Mountings		
1 ¾-in. deadweight safety valve	10 6	
1 thermometer	5 0	
1 ¾-in. emptying cock	4 6	
1 automatic damper regulator	18 6	
		1 18 6
1 9-in. by 9-in. C.I. soot door		6 0
Mains		
400 ft. run 3-in. diam. mild-steel water tube @ –/8	13 6 8	
250 ft. ,, 2½-in. ,, ,, ,, ,, @ –/7½	7 16 3	
180 ft. ,, 2-in. ,, ,, ,, ,, @ –/5½	4 2 6	
200 ft. ,, 1½-in. ,, ,, ,, ,, @ –/4	3 6 8	
140 ft. ,, 1¼-in. ,, ,, ,, ,, @ –/3	1 15 0	
60 ft. ,, 1-in. ,, ,, ,, ,, @ –/2½	12 6	
50 ft. ,, ¾-in. ,, ,, ,, ,, @ –/2	8 4	
20 ft. ,, ½-in. ,, ,, ,, ,, @ –/1¾	2 11	
		31 10 10
Fittings and Supports		
20 3-in. diam. black malleable bends @ 8/–	8 0 0	
12 2½-in. ,, ,, ,, ,, @ 5/–	3 0 0	
16 2-in. ,, ,, ,, ,, @ 4/–	3 4 0	
18 1½-in. ,, ,, ,, ,, @ 3/–	2 14 0	
10 1¼-in. ,, ,, ,, ,, @ 2/–	1 0 0	
12 1-in. ,, bends @ 1/6	18 0	
12 ¾-in. ,, ,, @ 1/1	13 0	
6 ½-in. ,, ,, @ –/8	4 0	
6 3-in. ,, black mall. tees @ 7/–	2 2 0	
4 2½-in. ,, ,, ,, ,, @ 6/–	1 4 0	
4 2-in. ,, ,, ,, ,, @ 3/3	13 0	
8 1½-in. ,, ,, ,, ,, @ 2/5	19 4	
6 1¼-in. ,, ,, ,, ,, @ 1/10	11 0	
2 1-in. ,, ,, ,, ,, @ 1/2	2 4	
3 ¾-in. ,, ,, ,, ,, @ –/10	2 6	
		25 7 2
2 3-in diam. longscrews @ 3/6	7 0	
3 2½-in. ,, ,, @ 2/9	8 3	
3 2-in. ,, ,, @ 1/6	4 6	
6 1½-in. ,, ,, @ 1/–	6 0	
4 1¼-in. ,, ,, @ –/9½	3 2	
2 1-in. ,, ,, @ –/7	1 2	
2 ¾-in. ,, ,, @ –/6	1 0	
2 ½-in. ,, ,, @ –/4½	9	
		1 11 10
46 3-in. diam. pipe brackets @ 1/2	2 13 8	
24 2½-in. ,, ,, ,, @ 1/–	1 4 0	
20 2-in. ,, ,, ,, @ –/8	13 4	
20 1½-in. ,, ,, ,, @ –/6	10 0	
Carried to page 2	5 1 0	116 14 4

TYPICAL ESTIMATING SHEET—*continued*

		£	s.	d.	£	s.	d.
	Brought forward	5	1	0	116	14	4
16 1¼-in. diam. pipe brackets	@ –/6		8	0			
12 1-in. ,, and below pipe brackets ..	@ –/4½		4	6			
					5	13	6
1 item for pipe sleeves						10	0
1 item for floor and ceiling plates					1	10	0
Radiators							
210 sq. ft. 18-in. high 4-col. radiators ..	@ 1/4	14	0	0			
170 ,, ,, 24-in. ,, ,, ,, ..	@ 1/3½	10	19	7			
80 ,, ,, 30-in. ,, ,, ,, ..	@ 1/3	5	0	0			
225 ,, ,, 24-in. ,, 3- ,, ,, ..	@ 1/6	16	17	6			
40 ,, ,, 24-in. ,, 2- ,, ,, ..	@ 1/6	3	0	0			
40 top stays	@ –/9½	1	11	8			
40 pairs bottom radiator brackets	@ 1/4	2	13	4			
8 1-in. diam. Ch.Pl. angle valves	@ 6/4	2	10	8			
12 ¾-in. ,, ,, ,, ,, ,, ...	@ 5/–	3	0	0			
20 ½-in. ,, ,, ,, ,, ,, ...	@ 3/–	3	0	0			
8 1-in. ,, ,, ,, elbow unions ..	@ 2/–		16	0			
12 ¾-in. ,, ,, ,, ,, ,, ..	@ 1/6		18	0			
17 ½-in. ,, ,, ,, ,, ,, ..	@ 1/2		19	10			
3 ½-in. ,, ,, ,, L.S. valves ..	@ 3/–		9	0			
1 key for lockshield valves			1	2			
					65	16	9
Valves							
1 2½-in. G.M. fullway valve	@ 11/3		11	3			
2 2-in. ,, ,, ,, ...	@ 9/–		18	0			
3 1¼-in. ,, ,, ,, ...	@ 5/4		16	0			
1 2½-in. ,, L.S. valves	@ 11/3		11	3			
2 2-in. ,, ,, ,, ...	@ 9/–		18	0			
3 1¼-in. ,, ,, ,, ...	@ 5/4		16	0			
3 keys, 1 for each size lockshield valve ..	@ 1/2		3	6			
					4	14	0
Feed Tank							
1 40-gal. galvd. cistern 12 gauge with 16-gauge cover ..		2	10	0			
1 ½-in. ball valve			3	0			
2 brackets			6	0			
15 ft. 1½-in. overflow pipe	@ –/4		5	0			
45 ft. ¾-in. feed pipe	@ –/2		7	6			
1 item for pipe fittings and spts.			8	0			
					3	19	6
Covering							
65 sq. ft. boiler surface 1½ in. thick and painted	@ 1/3	4	1	3			
30 ft. run 3-in. diam. pipe 1 in. thick and painted	@ 1/6	2	5	0			
20 ft. ,, 2½-in. ,, ,, ,, ,, ,, ,,	@ 1/3	1	5	0			
					7	11	3
Total net material costs					206	9	4
Labour, 420 hours fitter and helper ..	@ 2/9	57	15	0			
Travelling expenses		3	0	0			
Lodging allowances		10	0	0			
					70	15	0
					277	4	4
Item carriage and staff expenses..					2	0	0
					279	4	4
20 per cent. overhead charges		55	16	0			
10 per cent. profit		27	18	0			
					83	14	0
				Total	£362	18	4

NOTE.—The prices of the various items given are fictitious.

staff expenses, and to the sum of these the percentages for overhead charges and profit. Any provisional sums should then be entered, and the final total determined.

Specifications and Estimates

The specification and estimate should be accompanied by an explanatory letter giving the reasons for the inclusion of any particular type of boiler or radiator, etc., and the method of heating proposed. Any special features or conditions should be mentioned, in order that the possibility of such points being overlooked may be removed.

The estimate may be quoted as an item independent of the specification, or it may be included in the specification simply as a price clause. Where a number of prices have to be given as additions or alternatives, a summary sheet will assist the client in seeing at a glance and without confusion the amounts and totals.

In drafting the specification, care should be taken to describe clearly and succinctly the materials included and the extent of the work which the engineer proposes to undertake. Any work incidental to the installation, but not within the province of the engineer, should be referred to so that there may be no misunderstanding on such matters. It is, of course, the practice of most firms to send with their tenders a printed form of conditions upon which they are prepared to accept orders.

In a number of instances orders are given to the heating engineer by the general contractor acting on the instructions of the architect. If this is likely, the engineer should state clearly that the price quoted either includes a commission for the builder or is strictly net. In the latter case, any percentage which the architect thinks should be included for the general contractor must be added by him.

The following specification may be considered as typical of one for the installation of a low-pressure hot-water heating installation.

SPECIFICATION

The heating installation included in Estimate No. 1 to be a low-pressure hot-water system with circulation by gravity, and to be capable of maintaining a temperature of 60° in the heated rooms, when the outside temperature is 32°, and with a flow temperature at the boiler not exceeding 180° F.

The material to be supplied would be as follows :—

Boiler.—One cast-iron sectional boiler rated at 000,000 B.Th.U., complete with smoke pipe and stoking tools.

Mountings.—The boiler to be fitted with one deadweight safety valve, thermometer, altitude gauge, emptying cock, and automatic damper regulator.

Soot Door.—One cast-iron soot door and frame.

Mains.—The circulating mains fixed as shown on plan No. — to

be of "blue" water-quality mild-steel tube of standard weights and dimensions.

Fittings.—The pipe fittings to be of malleable iron easy-sweep pattern.

Supports.—The pipe supports of an approved pattern arranged to support the pipes at intervals of length not exceeding 8 ft.

Pipe Sleeves.—Pipe sleeves to be provided wherever pipes pass through walls or partitions.

Floor and Ceiling Plates.—The chromium-plated floor and ceiling plates where pipes pass through floors and ceilings.

Radiators.—Each radiator to be of an approved pattern and of a height and size suitable for its position. Each radiator to be securely stayed, supported on cast-iron brackets, and fitted with control valve and air tap.

Valves.—Each branch circuit to be fitted with gun-metal stop-valves on the flow and return pipes close to the junctions at the mains. The valve on the return to be of the lockshield regulating type. A suitable key for each size of lockshield valve.

Feed Tank.—One galvanised mild-steel cistern of — gal. capacity, complete with cover, and carried on suitable brackets. The tank to be fitted with ball valve, overflow pipe, and feed pipe to boiler.

Covering.—The boiler and circulating mains in the boiler house to be coated with plastic non-conducting composition, trowelled smooth and painted on completion.

In considering the specification given above, it should be understood that it is meant to convey the general method of setting out, and that more detailed descriptions of the plant offered may be necessary, especially if the tender is to be submitted to an architect or consulting engineer who will require the work to be of a certain standard.

In such cases, makers' names and Fig. Nos. should be stated, as well as test pressures, thicknesses of tank plates, and quality of lagging, etc.

RUNNING COSTS OF HOT-WATER HEATING SYSTEMS

Running costs, to the discriminating buyer, are frequently of more importance than the initial expenditure, and, as might be expected, the engineer is often asked, when submitting proposals for a hot-water heating installation, to give a fairly accurate estimate of the annual charges to be met.

It is generally sufficient if the fuel costs alone are given, and by sound reasoning and a little calculation it is possible to state the amount of coal or coke that is likely to be used during the heating season. It is not difficult to approximate very closely to the actual quantity of fuel that will be used, and a little trouble will enable the engineer to give figures which will prove reasonably correct.

If, as a result of guesswork, the estimated consumption is excessive,

the customer may turn down the scheme because of his inability or unwillingness to pay the fuel bills. On the other hand, if the figures given prove to be too low, the client is bound to feel that he has been deliberately misled.

Cost of Labour

The amount of fuel consumed does not, of course, cover all the running costs, and if these are to be complete, labour charges, maintenance, and insurance, interest on capital expenditure, and allowances for depreciation must be included.

On a small installation these items will not be considerable, as stoking will probably be part of the duties of a gardener or odd man who would be employed in any case.

For larger installations, where one or more stokers might be necessary, the cost of labour may be an item of sufficient importance to induce the client to consider automatic firing, either by mechanical stokers for solid fuel, oil burners, gas-heated boilers, or by using electricity. The engineer may then be asked to submit alternative balance sheets showing the difference in annual expenditure resulting from the use of fuels other than coal or coke.

Heating Requirements of Different Kinds of Buildings

In estimating the probable amount of fuel that will be used, consideration must be given to the type of building that is to be heated, and the heating requirements peculiar to that building.

In private houses, for example, the heating demands will be continuous from early in October until late in April, generally a period of thirty weeks.

In schools, the maximum internal temperatures are required only during school hours, usually from 9 a.m. to 4.30 p.m., and at week-ends and during the Christmas holidays the consumption of fuel will drop, as it will be necessary only to bank up the fires during these periods.

Many of the smaller churches and some of those in country districts are heated only at week-ends, but the saving effected is often negligible, because of the greater rate of stoking necessary when the fires are lit, to obtain satisfactory conditions by the time services commence.

Offices require to be fully heated only during office hours, and from, say, 6 p.m. until 7.30 or 8 a.m. the boilers can be banked up. At week-ends the banking-up period may be assumed to be between the hours of 1 p.m. on Saturday and 7.30 a.m. on the following Monday.

Although the average heating installation is designed to give the required internal temperature with an outside temperature of 32° F., the mean temperature for the winter months in England is approximately 42·5° F., so that it will be sufficient if two-thirds the maximum capacity is taken for the daytime requirements. Fifty per cent. of this, i.e. one-

third maximum, may be considered ample for the banking-up periods, and the average daily consumption can be computed in the manner shown below.

Estimating Cost of Fuel

Office building having maximum heating load = 650,000 B.Th.U. per hour, using coke as fuel at 12,500 B.Th.U./lb., and assuming boiler efficiency = 60 per cent.

$$\text{Then lb. coke per hour} = \frac{650000 \times 100}{12500 \times 60} = 86{\cdot}6.$$

Also, lb. coke *per diem* :—

From 8 a.m. to 6 p.m. = 10 hours @ 86·6 × ⅔	=	577·3
,, 6 p.m. to 8 a.m. = 14 hours @ 86·6 × ⅓	=	404·18
Total		981·48

From Mondays to Fridays, 5 days @ 981·48	=	4,907·40
Saturdays 8 a.m. to 1 p.m., 5 hours @ 86·6 × ⅔	=	288·65
,, 1 p.m. to 8 a.m., 19 hours @ 86·6 × ⅓	=	548·47
Sundays, 24 hours @ 86·6 × ⅓	=	692·8
Total lb. coke per week		6,437·32

Say, 6,440 lb./week.

$$\text{Total for 30 weeks} = \frac{6440 \times 30}{2240} = 86{\cdot}25 \text{ tons.} \quad \text{Say, 86 tons.}$$

The fuel bill with coke at 35*s.* per ton will be £150 10*s.*

To this, in order to give the total annual costs, it may be necessary to add an item for labour, say £1 per week, as part of a porter's or commissionaire's wages to be debited against the heating system, and an annual sum for interest and repayment on the capital expenditure, usually calculated at £8 7*s.* 4*d.* per cent.

Setting this out in tabular form, and including a further item for maintenance and insurances, we have :—

	£	*s.*	*d.*
Estimated cost of fuel	150	10	0
,, ,, of labour	30	0	0
Interest and repayment on capital expenditure of, say, £800 at £8 7*s.* 4*d.* per cent.	66	18	8
Maintenance and insurance, say	5	11	4
	£253	0	0

In making comparisons when fuels other than anthracite or coke used on hand-fired boilers are to be considered, it is necessary to make allowance for the increased capital expenditure due to the installation of more-expensive boiler plant or mechanical stoking equipment, the differences in cost of fuel, boiler efficiency, and labour costs.

Cost of Running Gas-fired Boilers

Thus, by the adoption of gas-fired boilers, an additional expenditure of £80 or more might have to be included.

The cost of gas consumed for the same B.Th.U. output from the boilers as reckoned in the preceding example can be calculated as follows, assuming boiler efficiency to be 80 per cent., and price of gas per therm 4*d.* :—

$$\frac{650000 \times 100}{100000 \times 80} = 8{\cdot}125 \text{ therms per hour.}$$

10 hours @ $8{\cdot}125 \times \frac{2}{3}$	$= 54{\cdot}17$
14 hours @ $8{\cdot}125 \times \frac{1}{3}$	$= 37{\cdot}917$
Total therms *per diem*	92·087

5 days @ 92·087	$= 460{\cdot}44$
Saturdays, 5 hours @ $8{\cdot}125 \times \frac{2}{3}$	$= 27{\cdot}08$
,, 19 hours @ $8{\cdot}125 \times \frac{1}{3}$	$= 51{\cdot}46$
Sundays, 24 hours @ $8{\cdot}125 \times \frac{1}{3}$	$= 65{\cdot}00$
	603·98

Say, 604 therms per week.

Then cost of gas for 30 weeks $= \frac{604 \times 30 \times 4}{240}$

$= £302.$

The balance sheet can now be prepared as follows :—

	£	*s.*	*d.*
Estimated cost of fuel	302	0	0
Labour (Nil)		—	
Interest and repayment on capital expenditure of, say, £880 @ £8 7*s.* 4*d.* per cent.	73	12	6½
Maintenance and insurance, say	5	17	5½
	£381	10	0

Note.—In the above computation it should be noted that the same B.Th.U. input to the building has been allowed. Actually, by the operation of thermostatic controls, the gas consumption would probably be much lower. There are also the advantages resulting from the cleanliness in the use of gas obtained by the absence of any dust or

ashes, the saving in fuel-storage space, etc., which cannot easily be reckoned in £ *s. d.*

Oil and Electricity

In the same way it will be found that oil and electricity, although considerably greater in cost than coal or coke when compared on a B.Th.U. basis, have advantages similar to those mentioned for gas. These are sufficiently important for serious consideration to be given to the alternative fuels named, especially in cases where the adoption of one or the other would be particularly suitable.

QUESTIONS AND ANSWERS

Why should Estimates be Numbered?

Because it frequently happens that one or more revisions may have to be submitted before the order is placed, and reference to them at a later date is simplified by this method.

What precautions should be observed in drafting a Specification?

Care should be taken to describe clearly and succinctly the materials included, and the extent of the work which the engineer proposes to undertake. Any work incidental to the installation, but not within the province of the engineer, should be referred to, so that there may be no misunderstanding on such matters. The conditions upon which the engineer is prepared to accept the order should be submitted with the tender in one form or another.

What are the Heating Requirements peculiar to (1) Private Houses, (2) Offices?

(1) In private houses, the heating demands will be continuous from early in October until late in April, generally a period of thirty weeks.

(2) Offices require to be fully heated only during office hours, and from, say, 6 p.m. until 7.30 or 8 a.m. the boilers can be banked up. At week-ends the banking-up period may be assumed to be between the hours of 1 p.m. on Saturday and 7.30 a.m. on the following Monday.

MATERIALS USED IN SANITARY WORK

CONCRETE

THE choice of a suitable basic material for concrete may be made from a variety of aggregates; the nature of the latter greatly affects the quality of the concrete, therefore care must be taken in selecting the correct material for the different branches of the work, as the strength of concrete varies according to the quality and relative quantities of the aggregate and cement.

SUITABLE AGGREGATES

Broken brick	Free from dust.
,, stone	,, ,, ,,
Thames ballast.	
Pit ,,	Free from clay, loam, or earthy matter of any kind.
Gravel	,, ,, ,, ,, ,, ,, ,, ,, ,, ,,
Shingle.	
Granite chips.	
Coke breeze	Free from sulphur, dust, and slag.

Brick, stone, ballast, gravel, and granite chips vary in size according to requirements, and range from 2-in. mesh to ½-in. mesh. If required, granite chips are obtainable much smaller, for mixing with cement or sand and cement for forming curbs, steps, pavings, and similar work where a hard-wearing surface is required.

Aggregate for Foundations

Brick, stone, ballast, and gravel are suitable for the heavier concrete where required in mass quantities such as foundations.

Floors, Partitions, etc.

Coke breeze is suitable for positions where lightness is desired, such as floors, partitions, and filling for hollow blocks; it is not suitable for damp situations or where great strength is required. Coke-breeze bricks and slabs are too well known to need description, but they are light, easily fixed, and make a good material for partition walls, etc., both in new work and in alterations to existing property. Where sanitary by-laws require a solid partition to separate a sanitary apartment from other rooms, breeze slabs suitably rendered fulfil this requirement.

Cement

The cement should be best-quality Portland, conforming in all respects to the British Standard Specification No. 12–1931, which deals with the manufacture, composition, sampling, testing, etc. To ensure the cement is of good quality, a clause should be inserted that "cement must conform to the B.S.S."

VARIOUS PROPORTIONS FOR CONCRETE IN SANITARY WORK

Aggregate								
Ballast	*Broken Brick or Stone*		*Gravel*	*Coke Breeze*	*Shingle*	*Granite Chips*	*Sand*	*Cement*
	Large	*Small*						
8								1
6							2	1
	6						3	1
	5						2	1
		6					3	1
		6					2	1
4							2	1
		4					1	1
			6				2	1
			5				1	1
				4			1	1
					5		1	1
					5			1
						4	1	1
						4		1
						3		1
						2		1

The relative quantities of sand and aggregate will vary in the case of ballast and gravel according to the amount of sand present in the aggregate.

Proportions for Drainage Work

The above Table gives a variety of proportions suitable for use in sanitary work. For drainage work alone, the specification laid down in the London County Council drainage by-laws is a useful one to adopt, and states that concrete shall be :—

"A conglomerate of clean gravel, hard brick broken small or other equally suitable aggregate with a sufficient quantity of clean sand, well mixed with cement in the proportion of not less than one part by measure of cement to eight parts of other material."

Selection of Aggregate

The selection of an aggregate is ordinarily governed by the materials obtainable in the locality, but careful consideration should be given to the nature and position of the work for which concrete is required. It may be that a contract is to be carried out in a district where a suitable aggregate is obtainable at a reasonable cost, and this is a consideration resulting perhaps in a great saving in cartage costs, etc.

Addition of Sand

Any of the foregoing materials may require the addition of sand to them in order to produce a suitable mixture, but in the case of ballast and gravel there is often sufficient sand present, and in some samples there may be an excess of sand. The latter is not a good point, and should be avoided by using properly screened material.

Amount of Sand

The type and size of aggregate to be used will govern the amount of sand required. For example, if an aggregate of broken brick or stone of 2-in. mesh is used, a fair amount of sand will be required to ensure that all "voids," i.e. spaces in the mass, shall be filled completely so as to give maximum solidity. The proportion of sand should be approximately 2 parts by measure to 4 parts by measure of broken brick or stone. The sand used must be free from earthy matter, and preferably of a coarse, gritty nature.

Water

The water for mixing should be quite clean, and free from organic and inorganic impurities. The quantity of water required per cubic yard of concrete varies from 21 to 30 gal. according to the nature of the aggregate.

Mixing

Much depends upon the way in which concrete is mixed. The materials should be accurately measured and turned over in the dry state until thoroughly mixed. Clean water is then added gradually by sprinkling through a rose, the mass meanwhile being turned over until it is thoroughly intermixed and every particle of sand and aggregate is coated with cement.

Too much water will produce a mass of aggregate covered with a thin wash of cement; which will be of little use, as the aggregate will sink, leaving a sloppy mass at the top. For positions where impermeability is required the correct type and quantities of aggregate, sand, and cement must be chosen, and the mixing must be uniform throughout so that the cement and sand fills all the voids in the mass. To refer to the Table, a mix of 4 coarse aggregate, 2 sand, and 1 of cement is a suitable mix for this purpose.

USEFUL DATA

22 cu. ft. of Thames ballast weigh 1 ton.
23 ,, ,, ,, coarse gravel ,, 1 ton.
24 ,, ,, ,, clean shingle ,, 1 ton.
22 ,, ,, ,, pit sand ,, 1 ton.
21 ,, ,, ,, river sand ,, 1 ton.
$\frac{7}{9}$,, yd. ,, sand weighs 1 ton.
1 ,, ,, ,, Portland cement ,, 1 ton 1$\frac{3}{4}$ cwt.

1 cu. ft. of Portland cement weighs 90 lb.
1 bushel ,, ,, ,, ,, 112 lb.
1 gal. ,, water ,, 10 lb.
1 cu. yd. of solid gravel before digging contains 27 striked bushels, and after digging contains 27 heaped bushels.
1 Imperial bushel = 1·284 cu. ft.
1 cu. ft. = 0·78 Imperial bushel.

BRICKS

Brickmaking is a chemical science, and the various earths used for their manufacture differ in quality and suitability, therefore the earths are intermixed and blended so that the necessary ingredients are present in sufficient quantity to form a good brick. Moulding is carried out either by hand or by machine ; the latter method is almost universally adopted in the large brickfields, the whole process being performed with costly machinery, producing great uniformity of result.

Characteristics of a Good Brick

(1) Should be thoroughly well burnt.

(2) When two are struck together, should produce a ringing sound.

(3) Should not break when thrown on the ground or against other bricks.

(4) Should be regular in size.

(5) Should be true in shape.

(6) Should have sharp arrises.

(7) Should have even surfaces.

(8) When tested with a pocket knife the blade should hardly make an impression, unless the brick is underburnt.

(9) Should be free from flaws, lumps, or cracks of any kind.

(10) When broken, the fractured surfaces should show incipient vitrification throughout.

(11) Should be uniform in colour.

(12) Should not absorb more than one-sixth of its dry weight of water after 24 hours' immersion.

Note.—The amount of absorption varies with the class of brick and the length of time immersed. This can be ascertained satisfactorily only by personal testing. A good stock brick should not absorb more than one-sixth of its dry weight of water. Some of the very hard varieties absorb as little as one-fifteenth of their weight.

Weight

The weight of a brick may be anything between 5 and 10 lb. according to the class of brick and its composition. Ordinary stocks are between 6 and 7 lb. ; pressed bricks 7 to 8 lb. ; blue Staffords 8 to 9 lb.

Simple Test

When two are struck together, the more or less metallic ring will be very pronounced in hard-burnt bricks, but dull in the case of soft bricks. A good facing brick should resist the knife. A good-quality brick will not break if thrown on to the ground. To fracture a brick, hold one end and strike the brick, about two-thirds along, against the edge of another one. The force required to break the brick, and the appearance and squareness of the fracture, will give some idea of the qualities of the brick. The structure should be uniform and compact.

Bricks used in sanitary work should be hard and non-absorbent, unless protected by an impervious coating such as asphalte, cement rendering, or tiling.

TYPES OF BRICKS AND THEIR USES

Type of Brick	*Uses*
Hard, well-burnt stocks	For general purposes, and the construction of manholes and cess-pools.
Brindled, hard, red and white mottled in appearance.	For the construction of manholes, sewers, etc.
Blue Staffords, plain	Where great strength is required ; for damp situations ; for copings.
Blue Ruabon	
Blue Staffords, chequered and grooved ..	For pavings, stable floors, etc.
White glazed	For interior and exterior facing work ; partition walls between sanitary apartments ; facing interiors of inspection chambers ; useful for reflecting light in enclosed areas : resist acid atmospheres.
Brown glazed	For facing work and partitions.
Dutch clinkers. Hard and bright buff or black in colour.	For paving, stable floors, etc.
Adamantine clinkers	,, ,, ,, ,, ,,
Malm paviors, hard, brownish yellow in colour.	For well steining.
Gault. Hard, rather difficult to cut ..	,, ,, ,,
Best, white in colour.	
Seconds, pink.	

SAND

The best type of sand for general use is pit sand ; the reason is because it is rough, angular, and sharp. Care must be taken to see that it contains no clay or other earthy matter, or this will be converted into mud when mixed with water.

River and Sea Sand

River sand is noted for its clean nature, but the grains are smooth owing to the continued action of water, and this lessens its value for building purposes ; the smooth grains prevent effective cohesion with the cement, i.e. they do not " key " so well as the rough grains of pit

sand. Sea sand, like river sand, has very smooth grains, and owing to the presence of salt it is not a desirable sand to use.

Washed Sand

Washed sand is often required, and is obtained by passing coarse sand through a fine-mesh sieve or screen in water. It is useful for many purposes in sanitary work; mixed with Portland cement it forms an excellent mortar for rendering the interiors of inspection chambers and for the facing coat for the benchings, giving a smooth surface. It is also used for mortar when making stoneware drain-pipe joints.

Testing

A simple test for sand may be made by rolling it in the hand or rubbing between the fingers; it should feel hard and gritty, and should not leave a stain. The sand that one may use on any particular class of work is usually specified, and the choice is not left to the person or persons carrying out the work. If, however, the specification should be worded as follows: "The sand to be clean, sharp, pit or fresh-water sand, coarse-grained and of an approved quality; to be entirely free from loam, clay, dust, or organic matter. If directed it must be washed when used with Portland cement"—it leaves one with a fair margin, so that should pit or river sand be available in the district, it could be used provided it complied with the requirements set out above. This would in many instances effect a great saving in cartage costs.

MORTAR

Mortar for all sanitary work should be composed of Portland cement and sand. Lime mortar is unsuitable. The proportions of cement and

TABLE—MORTARS FOR VARIOUS PURPOSES

Uses	*Sand*	*Cement*	
For ordinary walls	4	1	
For the construction of manholes and general items of drainage work	4	1	according to condition
	and 3	1	
Rendering manholes. First coat	3	1	
,, ,, Finish	2	1	
	or 1	1	
Construction of sewers in brick	2	1	
,, ,, cess-pools in brick	2	1	
Rendering of cess-pools	1	1	
Construction of rain-water tanks and filters	3	1	
	and 2	1	
Jointing pipe sewers and drain pipes	2	1	or neat cement
	or 1	1	
Curbs to gullies, etc.	1	1	
Well steining	3	1	

sand vary according to requirements, and range from 4 parts of sand to 1 part of cement, to 1 part of sand and 1 of cement. Opinions differ among many people as to the actual proportions necessary for certain kinds of work, but the Table on page 438 allows for a margin to suit most conditions. One must use discretion when deciding on the proportions necessary for any particular job. Mortar may be required to set "slow" or "quick," or it may be required "stiff" or "sloppy," according to the condition and position of the work. Cement that has once set should not be remixed for use, and it should be mixed in small quantities sufficient for immediate needs.

For pipe jointing, washed sand is recommended. Cement and sand shrinks approximately one-sixth in bulk when mixed with water.

PORTLAND CEMENT

Portland cement is the strongest type of cement, and derives its name from its resemblance to Portland stone. For the bulk of sanitary work it is the only suitable material to use, but for certain branches of the work there are other types of cement suitable for use, but they are of quite a different character and do not possess the same advantageous qualities or properties as Portland cement, such as strength, weather-resisting powers, and the ability to withstand constant washing by water. It has been mentioned in a previous section that Portland cement should conform to the B.S. Specification, and a few extracts are given here from the standard laid down in Specification No. 12–1931.

Manufacture and Composition

"The cement shall be manufactured by intimately mixing together calcareous and argillaceous and/or other silica, alumina, or iron oxide bearing materials, burning them at a clinkering temperature, and grinding the resultant clinker so as to produce a cement capable of complying with this specification. No addition of any material shall be made after burning other than calcium sulphate, or water, or both."

Samples for Testing

"A sample or samples for testing may be taken by the purchaser or his representative, or by any person appointed to superintend the works for the purpose of which the cement is required, or by his representative, or by any expert analyst employed or instructed by such purchaser or person, or by the representative of such purchaser or person.

"Each sample for testing shall consist of approximately equal portions selected from at least twelve different positions in the heap or heaps when the cement is loose, or from not less than twelve different bags, barrels, or other packages when the cement is not loose, or where there is a less number than twelve different bags, barrels, or packages, then from each bag, barrel or package."

Tests

" The sample or samples shall be tested . . . for :—
" (*a*) Fineness.
" (*b*) Chemical composition.
" (*c*) Tensile strength (cement and sand).
" (*d*) Setting-time.
" (*e*) Soundness."

Summary of Tests

(*a*) *Fineness.*—Residue on sieve of B.S. Mesh No. 170 not to exceed 10 per cent., and residue on sieve B.S. Mesh No. 72 not to exceed 1 per cent.

(*b*) *Chemical composition.*

(1) The hydraulic modulus (or ratio of lime to silica and alumina) to be not greater than 3·0 nor less than 2·0.

(2) Loss on ignition not to exceed—
3 per cent. in temperate climates.
4 per cent. in hot climates.

(3) Insoluble residue not to exceed 1 per cent.

(4) Magnesia not to exceed 4 per cent.

(5) Total sulphur calculated as sulphuric anhydride not to exceed 2·75 per cent.

(*c*) *Tensile strength* (*cement and sand*).—3–1 sand and cement mortar not less than 300 lb. per square inch at 3 days. Strength at 7 days to show an increase over that at 3 days and to be not less than 375 lb.

(*d*) *Setting-time.—Normal-setting cement.* Initial set of not less than 30 minutes, and final set of not more than 10 hours.

Quick-setting cement. Initial set of not less than 5 minutes, and final set of not more than 30 minutes.

(*The term " quick setting " does not necessarily imply that the cement hardens quickly.*)

(*e*) *Soundness.*—Expansion by the " Le Chatelier " test not more than 10 mm. (0·40 in.) or 5 mm. (0·20 in.) after 7 days' aeration. Time of boiling, 3 hours.

Sand for Testing

" The standard sand shall be obtained from Leighton Buzzard, shall be of the white variety, and shall be thoroughly washed and dried. Its loss of weight on extraction with hot hydrochloric acid shall be not more than 0·25 per cent."

OTHER CEMENTS

Plaster of Paris, " Sirapite," and Keene's

Plaster of Paris, " Sirapite," and Keene's cement are also used. Plaster is not used to a great extent but is useful for fixing marble slabs

and similar material where a quick-setting medium is required. Keene's cement is also used for this purpose, and being much slower in setting, allows the operator a greater margin of time in which to use it. "Sirapite" and also Keene's are useful materials for rendering the surfaces of walls, and both these materials permit of being trowelled to a very smooth surface. Plaster of Paris does not allow of such treatment. Plumbers sometimes make a practice of using plaster or Keene's to bed in the taps to earthenware lavatory basins and similar fitments, in place of an oil cement. When this practice is adopted with plaster of Paris, it should be remembered that a slight expansion takes place when plaster is mixed with clean water and allowed to set.

Rust Cement

By mixing together iron borings, flowers of sulphur, and sal-ammoniac in various proportions, a cement is obtained which rusts together and forms an iron-like mass. A rusting action takes place, and the iron borings combine with the sulphur.

This cement is used for various purposes, such as forming the joints in large, sectional, cast-iron tanks; the sections are flanged and the cement is rammed or caulked into the joints formed by the flanges, where it will "rust" or "set" slowly or quickly according to the proportions of borings, sal-ammoniac, and sulphur. It is sometimes used for jointing cast-iron socketed pipes in heating work, but it is not always successful, as cases have occurred where the expansion of the cement, due to the rusting action, has split the sockets of the pipes. It can be used as a medium for backing up an oil cement or other filling for socketed pipes, when the risk of fracture will be greatly minimised. When making rust cement the ingredients must be thoroughly mixed into a stiff paste, and when using it the packing must be well done to ensure a sound joint.

RUST CEMENT

Type	*Iron Borings*	*Sal-ammoniac*	*Flowers of Sulphur*
Slow-setting.. ..	200	2	1
Quick-setting ..	80	1	2

Oil Cements

Various mixtures of which oil forms a part, such as linseed-oil putty, litharge and glycerine, red and white lead, red lead and boiled oil, etc., are usually referred to as oil cements, and these may be prepared on the job as required, although linseed-oil putty is usually obtained ready prepared in small or large quantities. All compounds of lead are poisonous in nature, and when a cement composed of one or more of

these compounds is being used, cleanliness on the part of the user is essential. To overcome the use of these materials, several non-poisonous packing and jointing pastes have been introduced in recent years, and these are to be recommended. They are obtainable ready mixed for use, in tins of various sizes.

Oil cements are used for a variety of purposes. For screw-thread joints a liquid type is used, with or without a packing of hemp strands, according to the type of thread. If British standard taper-threaded tubes and fittings are used, hemp is unnecessary, as a metal-to-metal joint is formed by these threads, and all that is required is the application of the jointing paste or cement to the threads before screwing together to obtain a tight joint.

Red and white lead in conjunction with strands of yarn are often used for packing the joints of socketed cast-iron pipes in low-pressure hot-water heating work, alternate layers of yarn and cement being well packed into the jointing space. The use of red and white lead, mixed with chopped hemp to a very stiff form of putty, is allowed by some sanitary authorities for making the joints between pottery and soil and waste pipes. Red and white lead, painters' putty, or plain white lead are used for forming many of the joints between pottery ware and iron, brass, or lead. Although white lead alone is seldom used, it is claimed that for many purposes it is better than when mixed with red lead, as it gives a more elastic type of joint.

LEAD

Lead in one form or another is still used to a great extent in various building work, although perhaps not to the same extent as hitherto. Modern practice has brought into more extensive use those metals which are classed as "hard" for the conveyance and distribution of water supplies and waste matter, and also for roof coverings. Asphalte has replaced lead as a roof covering to a great extent. For chemical plumbing work, sheet lead or the lead alloys are still the only suitable materials to use.

Lead pipe sizes and weights for sanitary work are given in Data Sheet No. 26.

Traps and Bends

Lead traps and bends of various forms can be obtained in stock sizes from 1¼-in. to 4-in. internal diameter. The usual stock patterns are shown in Fig. 1, but almost any type may be made to order. This is most useful, especially where a large number of traps and/or bends is required for connecting up ranges of fittings such as water-closets, lavatory basins, or sinks. The use of a long-tailed P trap in certain positions saves the preparation and wiping of one joint, and in a range of fittings effects a great saving in time and solder. The long outlet

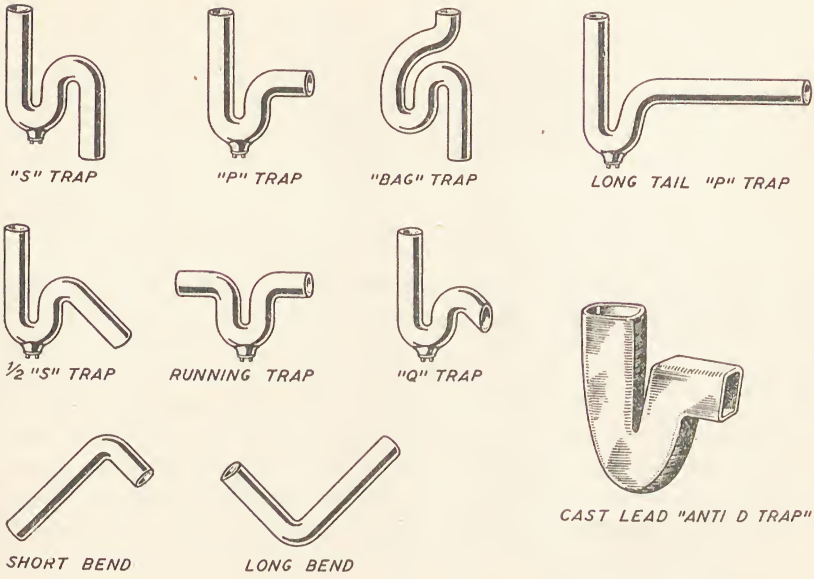


Fig. 1.—LEAD TRAPS AND BENDS

permits of a bend being formed, when required to make a proper connection, and obviates the preparation of short pieces of pipe.

Greenwood's "Anti-Vak" trap is fitted with an ingenious arrangement, in the form of a by-pass, which saves the use of anti-siphon pipes. When a discharge of water is taking place air is drawn through the

SHEET LEAD TABLE

Weight in Pounds per Square Foot	*Thickness in Inches*	
1	·016	$\frac{1}{64}$
3	·0508	$\frac{3}{64}$ full
4	·0677	$\frac{1}{16}$ full
5	·084	$\frac{3}{32}$ bare
6	·101	$\frac{7}{64}$ bare
7	·118	$\frac{1}{8}$ bare
8	·135	$\frac{1}{8}$ full
9	·152	$\frac{5}{32}$ bare
10	·167	$\frac{11}{64}$ bare
12	·203	$\frac{13}{64}$
15	·254	$\frac{1}{4}$ full
18	·304	$\frac{5}{16}$ bare
20	·338	$\frac{11}{32}$ bare
25	·423	$\frac{27}{64}$
30	·508	$\frac{1}{2}$ full

From the Table compiled by Peter Hunter, M.I.Mar.E.

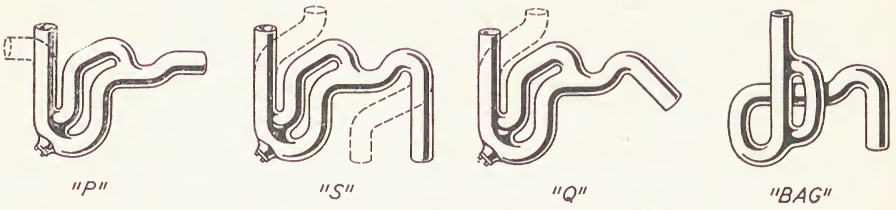


Fig. 2.—GREENWOOD'S "ANTI-VAK" TRAPS

by-pass from the inlet side of the fitting; the pocket arrangement on the outgo retains a quantity of water, and as soon as the discharge ceases the retained water falls back and seals the trap. These traps are made in a variety of patterns to suit the layout of any particular job, and are approved by most sanitary authorities as conforming to the by-laws. They are particularly useful in positions where an anti-siphon pipe is a somewhat difficult and expensive item to install, and the use of these traps does away with the trap ventilation pipe, with its accompanying branches from each trap, and the wiped joints or other connections required in a range of fittings.

LEAD COMPOUNDS

White Lead

One of the most important properties of lead is that it may be converted into useful compounds, of which two are white lead and red lead. White lead is obtained by "corroding" the metallic lead with the aid of tan and acetic acid. "Genuine stack-made lead" is a familiar sign, and the operations involved in converting the metallic substance into white lead occupy a period of from three to four months. The stack is formed of alternate layers of tan and pots of acid, and across the tops of the acid pots, thin strips of lead about 4 in. wide and 15 to 18 in. long are laid zigzag fashion. The height of the stack is about 18 or 20 ft. Heat is generated by the tan, the acid fumes attack the lead, corroding it and converting it into a white powder which is the *carbonate of lead*.

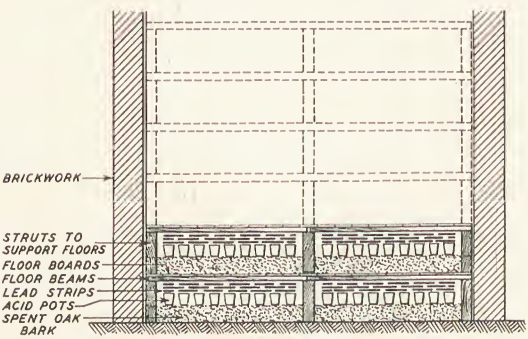


Fig. 3.—DIAGRAMMATIC SECTION THROUGH STACK FOR WHITE-LEAD PRODUCTION

This action continues until the corroding process is complete, when the stack is dismantled and the pieces of lead, thickly coated with the carbonate, are removed in trays and shot into a perforated revolving drum

where the whole of the powder is removed, and the metallic lead which remains is ejected on to a travelling belt and conveyed to the melting-pot, from where it is recast into strips. The carbonate is collected, ground, and finally mixed with oil in a revolving drum to form the stiff white paste with which we are familiar.

Chamber Process

By this process the time required is much shorter than in the stack method, four or five weeks being the usual time taken to corrode the metallic lead. Strips of lead are suspended from wooden spars inside a chamber in which there are openings which admit acetic acid fumes, steam, and carbon dioxide.

Red Lead

If a pot of metallic lead is heated in the open air, a skin or film forms on the surface of the lead ; if this is scraped to the side of the pot, a mirror-like surface appears, but soon tarnishes owing to the action of the air. If this operation is repeated the whole of the metal would be converted into a form of dross. This in effect is the method of production of red lead. The first operation consists of heating the lead in a current of air to form lead oxide, and this will be of a yellow colour and called *massicot* ; if a greater heat is applied it gives a brownish-coloured mass called *litharge*.

If massicot is heated in air, it absorbs oxygen and is converted into *red lead*, the bright-coloured powder familiar to the decorator, plumber, and fitter.

Other Lead Products

Lead wool and rope are substances which have been introduced to overcome the labour involved in heating a pot of lead and the subsequent carrying of the molten lead for forming caulked joints in cast-iron pipes. Lead wool consists of finely cut fibres of lead twisted together to form skeins. It possesses many advantages over molten lead : no fire is required; caulking clamps or clay bands to retain the lead are unnecessary; it can be used with safety in damp positions, where the use of molten lead might prove a source of danger if coming in contact with moisture. It is easy to manipulate, and may be consolidated by the use of ordinary caulking tools. Leaded yarn is spun yarn covered with a thin lead sheathing. The

Fig. 4.—LEAD WOOL

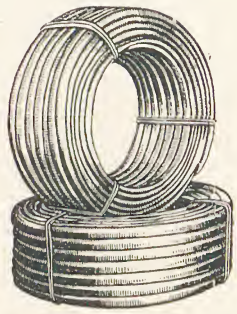


Fig. 5.—LEADED YARN

object of this sheathing is to protect the yarn from contact with liquid matter passing through the pipes. The lead yarn is pressed into a flattened section of the right size for inserting into the annular joint space of a socket, after which it may be easily caulked in the usual way.

Lead Alloys

Much research work has been carried out in recent years to produce an alloy of lead which possesses all the inherent advantages of ordinary lead, and in addition has certain properties which enable it to stand much greater stresses and strains. Ternary alloy lead and tellurium lead are now well known as lead alloys which have been introduced to overcome many of the setbacks which have been met with in cases where ordinary lead has been used. They are capable of resisting corrosion and vibration stresses to a high degree, and experiments have proved that pipes of these metals withstand a much higher resistance to bursting than do ordinary lead pipes ; this enables a pipe to be used which is of lighter gauge than ordinary lead. These alloys may be joined by soldering in the same way as ordinary lead, and both are suitable materials for use in sanitary work.

Owing to their acid-resisting qualities they are admirably suited for work in connection with chemical plumbing.

ZINC

Zinc in a variety of forms is used for many purposes in building. It is well known as a material for roofing purposes, and may be said to form a light, easily fixed, and economical covering. If it is properly fixed, the effective life of zinc is about thirty years. It is less expensive than lead or copper, but is less permanent than either of those two metals. For certain classes of work, such as turrets and ventilators, it is particularly suitable. When exposed to certain atmospheres it becomes coated with a film of zinc oxide, which, however, acts as a protective coating and prevents further action, whilst certain acid atmospheres have a destructive action on the zinc.

Sheets

For roofing purposes, zinc sheets are rolled to a variety of thicknesses varying from Nos. 8 to 18 gauge, and to different sizes, and may be obtained 6 ft. by 3 ft., 7 ft. by 3 ft., and 8 ft. by 3 ft. The last named is a useful size for the general run of roof work. The gauges for good-class work should be not less than No. 16 for gutters and No. 14 for flats.

Zinc Eaves Gutter

This type of gutter is made up from the sheet material, but unless specially ordered is of a flimsy character. It is a very light form of guttering even when made of the heavier gauges of zinc, and when

properly stiffened by interior cross-stays or supports and suitably fixed it will last a considerable time. Unlike cast iron, it does not require periodical painting in order to preserve it, although it is often painted for the sake of appearance. Ordinary oil-paint does not "key" to zinc, owing to the smooth nature of the latter, and when the paint has thoroughly dried out it easily flakes off. Zinc eaves gutters usually suffer a fair amount of damage by ladders being placed against them during repair or redecoration of premises.

Zinc Piping

This is also made up from the sheet material, and like guttering is usually of a flimsy character unless specially ordered to be made of heavier zinc. It is not a suitable form of pipe to use where a lasting and permanent job is required.

Protective Qualities

Although zinc is viewed with disfavour by many as being unsuitable for work of a permanent character, it plays an important part in the protection of other metals, such as iron and steel, in the form of "galvanising." This is especially the case in respect of much of the material used in sanitary work, and galvanised-iron goods are extensively used in the form of water pipes and fittings, soil and waste pipes and fittings, air bricks, wall ties, nails, manhole steps and covers, etc. In this form zinc may be said to be a very important material.

TABLE—ZINC GAUGE

(Thicknesses and Weights are approximate)

Gauge	*Thickness in Inches*	*Size and Weight of Sheets*		
		6 ft. by 3 ft.	*7 ft. by 3 ft.*	*8 ft. by 3 ft.*
		lb. oz.	*lb. oz.*	*lb. oz.*
9	0·018	11 9½	13 9	15 8
10	0·020	12 14	15 0	17 2
11	0·023	15 0	17 8	20 0
12	0·026	17 0	19 14	22 10
13	0·029	19 1	22 4	25 7
14	0·032	21 1½	24 10	28 2
15	0·038	24 7½	28 8	32 9
16	0·043	27 14	32 8	37 2

IRON

Iron in one form or another is used extensively in sanitary work, and is usually referred to as cast, wrought, or malleable. There are

three varieties of cast iron: grey, mottled, and white. Grey iron is used for castings, and also for converting into steel. Mottled iron is used where extra strength is required, because of its tough character. White iron is used for conversion into wrought iron, being extremely hard.

Coatings

Much of the iron used in sanitary work is protected by galvanising, as mentioned in the section on zinc. Another well-known protective coating, which is applied to a large amount of iron goods, is Dr. Angus Smith's solution. The composition of this coating varies with different manufacturers, but the British Standard Specification No. 437–1933 gives a standard composition and method of application of the coating to cast-iron pipes, as follows: "The pipes shall be thoroughly cleaned, and before rusting has begun shall be dipped in a bath containing a composition having a tar basis and maintained at a temperature between 290° F. and 330° F. The preparation of the ingredients of the composition shall be so regulated as to produce a coating of the quality hereinafter specified. When the pipes are removed from the bath they shall be properly drained, and the coating shall fume freely and set solid within an hour. The coating shall be smooth and tenacious. It shall not flow when exposed to a temperature of 145° F., and shall not chip off when scribed with the point of a penknife at a temperature of 32° F. Any pipe which is imperfectly coated, or the coating of which does not fume and set or conform to the quality specified above, shall be recoated."

The Bower Barff process is another method in which a protective coating in the form of a black magnetic oxide is applied by subjecting the articles to the action of superheated steam; this forms a smooth, compact layer which protects the metal beneath. Iron may also be protected by coating with lead, tin, copper, aluminium, brass, and bronze. The Schoop gun is a device used for spraying molten metal, an air blast being used in conjunction with an oxy-hydrogen flame or an electric arc. Nickel plating, chromium plating, and porcelain enamelling are other forms of coating used for ironwork. Painting and tarring are two of the simplest methods of protection.

Reasons for Protective Coatings

As a general rule, metals oxidise in the air; this is especially the case with ordinary iron, and a coating of scale or iron rust forms; in time this scale cracks and falls away, leaving a fresh surface of the metal open to the action of the air. Further oxidation takes place, and in time the iron is destroyed; the action is increased by the presence of acids in the air.

Typical Examples of Rusting

The necessity of using a protective coating for any ironwork used in sanitary work is emphasised by the following examples of what takes place should this protection be omitted.

(1) The under side of unprotected inspection covers of drainage manholes will often be found badly rusted.

(2) The interiors of the top lengths of uncoated soil pipe vent-shafts will often be found badly rusted, and in some cases perforated.

(3) The backs of rain-water pipes which are fixed flat against the wall, so that it is impossible to paint them, usually become perforated, whilst the portion protected by paint is quite sound.

(4) Cast-iron eaves gutters suffer in a similar way to rain-water pipes. This may be observed when a cast-iron gutter is disturbed after a few years' use ; flakes of rust will fall away, and the back of the gutter found to be almost destroyed.

(5) Iron air bricks are often found to be as thin as paper, due to rust.

(6) Iron dowels used for stonework have been known to corrode and expand considerably, and in doing so have caused stonework to be moved from position.

In addition to the above examples there are many other forms of rusting which occur, such as the interiors of cast-iron flushing cisterns, water pipes, boilers, etc. It follows that some form of protection is necessary in order to preserve the metal and to prevent discoloration of water. It should, perhaps, be pointed out that the rusting of iron is dealt with here only in a simple manner, for actually the rusting or corrosion process is complicated ; in many cases electrolytic action takes place and this would require a fair amount of explanation, beyond the scope of this article.

Wrought-iron Tubes

Tubes of wrought iron are usually referred to as being of gas, water, or steam strength. They are usually recognised by colour ; gas tube is black, water tube is blue, and steam tube is red. For purposes of water supply, the Metropolitan Water Board by-laws state that : " Every pipe and fitting of wrought iron or steel shall be of ' steam ' pipe strength in accordance with the Table [at top of page 450], and shall be efficiently protected against corrosion, and any malleable cast-iron fitting used in connection with any such pipe shall also be of steam strength."

Cast-iron Pipes

" Every service pipe or distributing pipe of cast iron shall comply with the B.S. Specification for water pipes for a test pressure equal to

double the working pressure to which the pipe will be subjected under normal working conditions. Provided that no service pipe shall be of a lower standard than Class 'C,' Table No. 1, of such specification."

TABLE

Nominal Bore of Pipe in Inches	*Approximate Outside Diameter of Pipe in Inches*	*Thickness of Pipe, I.S.W.G.*	*Number of Threads per Inch*
$\frac{1}{2}$	$\frac{27}{32}$	10	14
$\frac{3}{4}$	$1\frac{1}{16}$	9	14
1	$1\frac{11}{32}$	8	11
$1\frac{1}{4}$	$1\frac{11}{16}$	7	11
$1\frac{1}{2}$	$1\frac{29}{32}$	6	11
2	$2\frac{3}{8}$	6	11
$2\frac{1}{2}$	3	5	11
3	$3\frac{1}{2}$	5	11

Note.—It should be noted that the first column in the Table is an index to the particulars given in the Table, and does not fix the internal diameter of any pipe. When pipes of a nominal bore exceeding 3 in. but not exceeding 6 in. are used, the Board suggests that they should comply with the requirements specified in the third and fourth columns of the Table for pipes of a nominal bore of 3 in.

Iron Drain, Soil, Waste, and Vent Pipes

The sizes and weights of cast- and wrought-iron pipes as required by the London County Council by-laws are as follows :—

CAST-IRON DRAIN PIPES

Internal Diameter	*Internal Depth of Socket not less than*	*Caulking Space not less than*	*Thickness of Metal for Pipes and Fittings not less than*	*Weight of Pipes (including Socket and Beaded Spigot or Flanges) not less than*
in.	*in.*	*in.*	*in.*	
2	$2\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	42 lb. per 6-ft. length
3	3	$\frac{5}{16}$	$\frac{5}{16}$	98 lb. ,, 9-ft. ,,
4	3	$\frac{5}{16}$	$\frac{3}{8}$	157 lb. ,, ,, ,,
5	3	$\frac{3}{8}$	$\frac{3}{8}$	186 lb. ,, ,, ,,
6	$3\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	225 lb. ,, ,, ,,
7	4	$\frac{3}{8}$	$\frac{7}{16}$	316 lb. ,, ,, ,,
8	4	$\frac{3}{8}$	$\frac{15}{32}$	370 lb. ,, ,, ,,
9	4	$\frac{3}{8}$	$\frac{1}{2}$	441 lb. ,, ,, ,,

SOIL, WASTE, AND VENT PIPES

Internal Diam.	*Cast Iron*				*Wrought Iron*	
	Internal Depth of Socket not less than	*Caulking Space not less than*	*Thickness of Metal for Pipes, Traps, and Fittings not less than*	*Weight of Pipes per 6-ft. Length (including Socket and Beaded Spigot or Flanges) not less than*	*Thickness of Metal for Wrought-iron Pipes and Wrought-iron, Cast-iron, or Malleable-iron Traps or Fittings not less than*	*Weight of Pipes per Yard (not including Sockets or Flanges) not less than*
in.	*in.*	*in.*	*in.*	*lb.*	*in.*	*lb.*
$1\frac{1}{4}$	—	—	—	—	0·176*†	7·94†
$1\frac{1}{2}$	$2\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	22	0·192*	9·82
2	$2\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{16}$	24	0·192*	12·51
$2\frac{1}{2}$	$2\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	30	0·212*	17·64
3	$2\frac{3}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	35	0·212*	20·82
$3\frac{1}{2}$	3	$\frac{1}{4}$	$\frac{3}{16}$	41	0·212*	23·97
4	3	$\frac{1}{4}$	$\frac{3}{16}$	46	0·212*	27·13
$4\frac{1}{2}$	$3\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	66	0·212	30·3
5	$3\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	78	0·212	33·45
6	$3\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{4}$	92	0·212	39·78

* The foregoing by-laws, except so much of the Table numbered (3) (three) in the schedule as requires a greater thickness of metal than is specified in the second column in this certificate for malleable-iron traps, and fittings of an internal diameter not less than is specified in the first column opposite to each thickness—

in.	*in.*	*in.*	*in.*	*in.*	*in.*
$1\frac{1}{4}$	·13	2	·16	3	·19
$1\frac{1}{2}$	·14	$2\frac{1}{2}$	·17	$3\frac{1}{2}$	·19

—are hereby allowed by the Minister of Health, 28 July, 1934.

† In virtue of by-laws 6, 8, 9, and 10, the practical application of this size of pipe in wrought iron is limited to partial reconstruction or repair of existing pipes of less than $1\frac{1}{2}$-in. internal diameter.

SANITARY SCIENCE APPLIED TO BUILDING

PART V.—WATER SUPPLY

THE provision of a wholesome supply of water to buildings in towns where there is a public water undertaking is usually a simple matter, as distributing mains are available from which a communicating pipe may be taken to supply the premises.

Supply in Outlying Districts

In outlying districts, where main supplies are not available, recourse must be had to water obtained from wells or springs, whilst in many cases use is made of rain-water for many purposes. Much depends upon the geological formation of the surrounding country as to which of these methods will be the most suitable to produce a satisfactory supply of water. Haphazard methods should not be resorted to, but advice should be sought from a reputable firm of water engineers who specialise in this class of work.

Source of Water

The available sources may be classified as follows :—

(1) Streams and rivers.
(2) Lakes and ponds.
(3) Collected rain-water.
(4) Shallow wells.
(5) Deep wells.
(6) Springs.

All supplies of water are derived ultimately from the rainfall. Many underground waters are the result of percolation of rainfall from the surface over a very long period of years, and in many instances good use is made of the underground lakes for providing an abundant supply of water. The class of water obtained from underground sources will depend upon the formation of the strata through which it has passed in its downward course. Waters from open or running streams are more or less contaminated, as they are fed chiefly by water from the surface and which may have drained from cultivated lands. The use of water from such a source, where a proper system of purification cannot be adopted, must be confined to areas where the gathering grounds are

uninhabited and so remote as to be absolutely free from pollution; although streams are to some extent self-purifying, due to aeration, such as splashing, etc., too much emphasis must not be laid on this point. The water obtained from lakes may be looked upon as good providing that a good stream of water is entering and passing out of them; precautions must, however, be taken to prevent pollution from surface matter or fouling by cattle, etc.

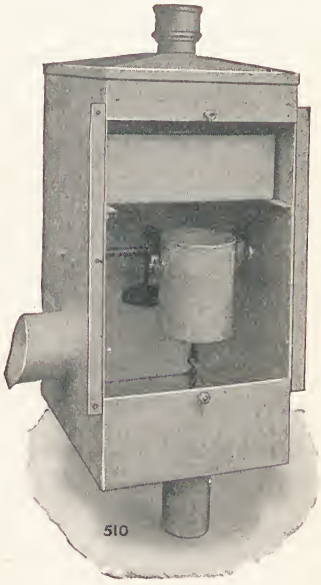


Fig. 1.—RAIN-WATER SEPARATOR

The first flow of roof washings passes to waste. (*Tuke and Bell Ltd.*)

RAIN-WATER

In its pure state, rain-water is the purest of all waters occurring naturally. In its descent it absorbs gases from the atmosphere, and it also contains in solution or suspension particles of dust and various other impurities which may be present in the atmosphere. These impurities are due to the products of combustion of coal, sulphuric acid, and sulphates, and usually present in the air of towns. Rain-water is very soft, and is therefore useful for many purposes. It is not so well aerated as ground water, and to the taste is flat and insipid and not very palatable. The use of rain-water direct from collecting areas is used far more than is generally supposed. In districts where use is made of the rainfall for supply purposes, various methods are adopted for its collection, purification, and storage. The use of rain-water is in many cases supplementary to another source of supply, whilst in others the rainfall is the only means of supply for all purposes.

Collection of Rain-water

The collection may be from roofs, which are in effect ready-made areas, and may be constructed on suitable lines to meet the needs of the premises. Where the roof area is insufficient, special collecting areas or gathering grounds are constructed and may consist of a suitably paved surface such as concrete or tiles, or an area of corrugated iron sheeting. Another method sometimes adopted is to lay out a large area of clean earth over an impervious layer such as concrete; grass is then sown, and the rain percolates through the layer of earth on to the bed, which is sloped to fall to a channel or channels, the water then being conducted by a pipe line to the storage vessel. Collecting areas of this type should be well protected against pollution or fouling by

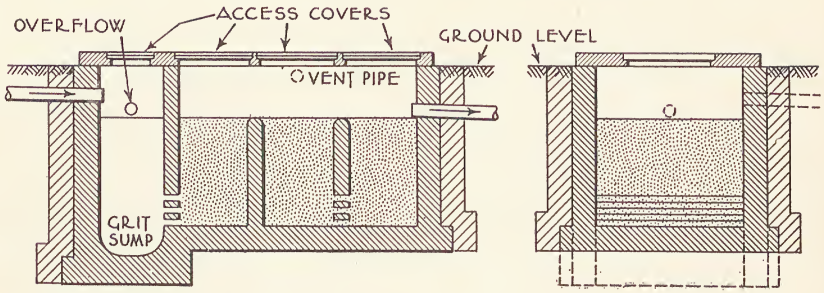


Fig. 2.—PRIMARY UNDERGROUND FILTER FOR RAIN-WATER

Filtering medium: ballast, coarse gravel, or clean unglazed drain pipe broken small. Construction: reinforced concrete rendered inside with Portland cement and sand, exterior backed with clay puddle. Galvanised or coated iron manhole covers for access purposes. Inlet, outlet, and overflow pipes fitted with stout wire-meshed guards. If levels permit, grit sumps to be provided with washout pipe and valve.

straying cattle, etc. The districts where rain-water is the only source of supply are often situated in isolated open country, where the atmosphere is comparatively clean and free from the impurities usually found in the atmosphere of more thickly populated areas, so that the collected rain-water would be of a fairly clean character. Where roofs are used for the collecting surface, there are usually present such impurities as soot, bird droppings, decaying leaves, etc. For this reason it is essential that the first part of the rainfall should be utilised for washing the roof areas, and not allowed to pass to the potable water storage. The use of a rain-water separator is to be recommended, as this apparatus allows the first portion of the rainfall to pass through to waste or to a separate storage, after which the clean water is conducted to the primary storage vessel (Fig. 1). The latter is usually constructed underground, and the layout includes a primary storage vessel, filter, and a clean-water storage vessel. From the latter the water is pumped into tanks within the building for distribution to various points. In many cases the water is used without any primary purification, but it is safer to adopt a process whereby it may be rendered more suitable for potable purposes.

Filtration of Rain-water

Rain-water may be filtered by passing it through an ordinary simple filter composed of sand and gravel. The filter must be constructed of sufficient capacity to deal with the volume of water which may fall in time of very heavy rain. It may be constructed of brickwork, rendered on the inside with Portland cement and sand, or of reinforced concrete similarly faced, and in each case backed with clay puddle 9 in. thick. The base of the filter may be fitted with perforated pipes or with bricks laid in rows. An overflow pipe and a vent-pipe should be provided. It is essential, for the proper working of the filter, for the filtering medium

to be changed at intervals (Figs. 2 and 3).

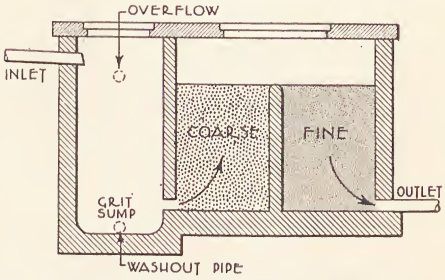


Fig. 3.—RAIN-WATER FILTER, SUITABLE FOR USE ABOVE GROUND

Storage Tanks

An underground tank may be constructed of similar materials and in a similar manner to that described for the filter. It may be either square or circular in plan. The clay puddle is essential in order to prevent the passage, into the tank, of water which may be polluted (Fig. 4).

Cover

The tank should be constructed so that the cover is well above the surrounding ground, to prevent the entry of splashings and washings, etc. A cover to a rain-water storage tank is essential, as the influence of sunlight is liable to cause vegetable growths which are objectionable. A covered tank also keeps out dust and other forms of contamination, and further, the water keeps in better condition when stored in the darkness of a covered vessel. The filter and storage tank should be built well away from any possible source of contamination, such as cess-pools, dung heaps, etc.

USE OF WELLS FOR SUPPLIES

The sinking of deep wells or borings in order to obtain a supply of water for large buildings is quite common practice in many parts where there is also available a supply from the town mains. Many of our

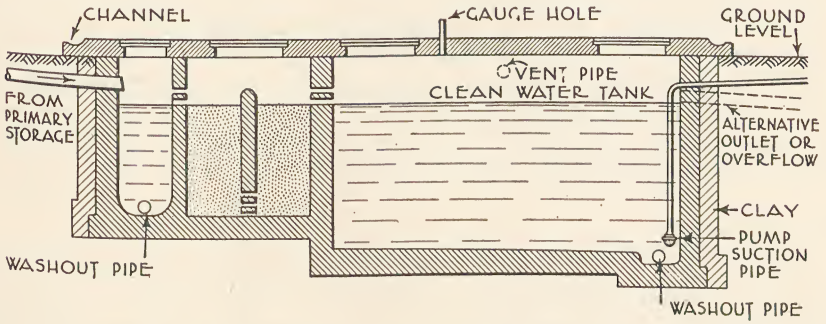


Fig. 4.—COMBINED FILTER AND STORAGE TANK FOR RAIN-WATER, CONSTRUCTED ON THE SAME PRINCIPLE AS FIG. 2.

Filtering medium, fine and coarse sand. Size of actual storage, 15 ft. by 8 ft. by 6 ft. effective depth. 4,500 gal.

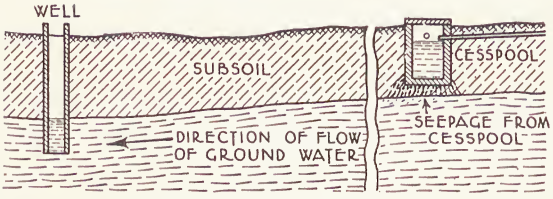


Fig. 5.—WRONG SITE FOR WELL

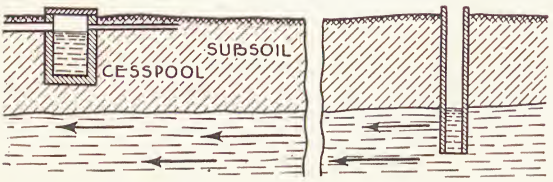


Fig. 6.—CORRECT SITING FOR WELL

London buildings obtain their supply by this means, the water being drawn from the chalk basin some hundreds of feet below the surface. Deep-well bore-hole pumps or compressed-air lifts are used for raising the water, after which it is passed into storage tanks of large capacity. In some instances the water is subjected to certain treatment before consumption. Large numbers of industrial premises also obtain their supplies from deep wells bored on the premises.

Shallow Wells

Wells of a shallow type are often used for the purpose of obtaining a supply of water, but as wells of this type are fed from the subsoil or ground water from the upper layers they should be viewed with suspicion, especially where there is any likelihood of pollution from leaky cess-pools, drains, or from the presence of manure heaps, etc. Reference has been made to the movement which takes place with ground water, and the possible dangers which may arise from the pollution of well water is especially applicable to areas in the vicinity of shallow wells, as polluted ground or surface water may easily pass into them. Waters from shallow wells are sometimes charged with inorganic impurities arising from decomposing animal and vegetable matter. The disadvantage of a shallow well from the point of view of pollution may be greatly minimised if care is given to the selection of a suitable site and to the proper construction of the well. The class of water obtained from a shallow well will depend upon the nature of the subsoil ; gravel and sand would produce a soft water, whilst chalk, sandstone, and limestone would give water of a hard nature.

Site for Well

The site for a shallow well must be selected with due consideration for the quantity and quality of the water likely to be obtained, the direction of the flow of ground water, and the position of fouling influences —such as cess-pools and middens or similar items—in relation to the proposed site. The well should be sited so as to intercept the water flowing towards the area of likely pollution, and should be situated at least from

80 to 100 ft. away from a cess-pool or like receptacle for sewage. If it is not possible to form the well in such a position, the distance between the area of possible pollution and the proposed site should be such as to permit of adequate natural filtration of the water before it enters the well (Figs. 5 and 6).

Abyssinian Tube Well

This is a well formed by driving into the earth a series of tubes having screwed joints. The first tube is formed with a point or spear-head to assist its passage into the earth. Just behind the point the tube is perforated, and this acts as the rose when water is reached. The tubes are screwed together as sinking proceeds, and are driven in by means of a special monkey to a depth of from 20 to 25 ft. The latter depth should not be exceeded. When water of sufficient quantity has been reached, a pump is fitted to the top tube at ground level and "primed," i.e. charged with water. Pumping is commenced, and the first water brought up will be cloudy owing to the presence of sandy matter. After a time a cavity is formed around the perforated tube end, and this acts as the well, and clean water may be pumped. This type of tube well is suitable only for certain soils, such as coarse sand or gravel ; it cannot be driven into hard formations, and it is unsuitable for the softer types of earth which would tend to clog the perforated tube.

Why the Depth Should Not Exceed 25 ft.

The pump used with this class of tube well is the ordinary "jack" pump, which raises water to the level of the discharging nozzle. The theoretical limit to which water can be raised by a pump of this type is approximately 33 ft. 10 in., i.e. the height of a column of water which a pressure of one atmosphere will support. The practical limit is sometimes given as 28 ft., but experience has shown that 25 ft. is a safe limit for the lift from the surface of the water in the well to the top of the pump bucket. To arrive at the theoretical limit : divide the pressure of atmosphere at sea-level (14·7 lb. per square inch) by the weight of a column of water 1 sq. in. in area and 1 ft. high (0·434 lb.),

$$\therefore \quad 14{\cdot}7 \div 0{\cdot}434 = 33{\cdot}88 \text{ ft.}$$

For deep wells, a pump of a different type must be used, because of this limitation.

Deep Wells

These wells obtain their supplies from the lower strata, and because of this they are less liable to become polluted. It is, however, possible for pollution to occur by the passage of organic matter down the sides of the well, although this may be greatly minimised if due care is taken in the construction of the well to prevent the possible entry of such

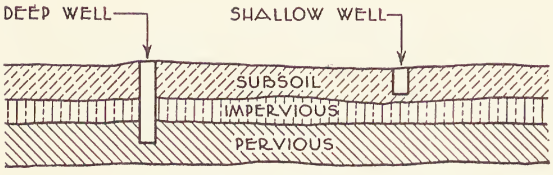


Fig. 7.—SINKINGS FOR DEEP AND SHALLOW WELLS

matter. Pollution may also occur by the passage of organic matter along fissures in the strata which connect with the well. The construction of this type of well is an expensive item, and bore-holes are now usually adopted. The advantage of deep wells is that the pumps may be fixed a few feet above the water level, where they may be inspected or repaired as and when required. The disadvantages are high cost of construction and difficulty in keeping out surface and subsoil water. The water obtained from deep wells varies chiefly owing to the nature of the subsoils through which it passes before reaching the lower levels. It is often very hard, and highly charged with earthy and mineral matters which have been dissolved out by the water in its downward course.

The selection of a site for a deep well calls for careful investigation, and is a matter which should be placed in the hands of a specialist firm (Fig. 7).

Artesian Wells

These provide a useful source of water supply of a very good quality. Artesian wells are those which are sunk through an impervious (non-porous) stratum into a pervious (water-bearing) stratum, when the water will rise within the well to a level varying with the position of the boring in relation to the level of the water table or source of supply to the underground storage. This level may be such that the water at the point of tapping will be at considerable pressure, which may be sufficient to cause water to rise a considerable distance within the well, or it may be sufficient to cause the water to overflow at the surface ; these wells are termed non-flowing or flowing accordingly. In the case of a non-flowing Artesian well, the water may rise sufficiently high to permit of pumps being fixed at ground level.

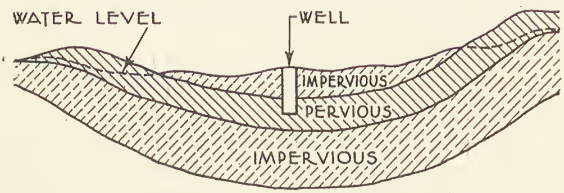


Fig. 8.—ARTESIAN WELL TAPPING UNDERGROUND SUPPLY BETWEEN TWO IMPERVIOUS BELTS

The lower impervious belt or layer forms a basin.

London Basin

A very good example of an underground supply tapped by Artesian wells is that of the London basin, which is a naturally formed reservoir of chalk, the non-porous strata being as seen in Fig. 9.

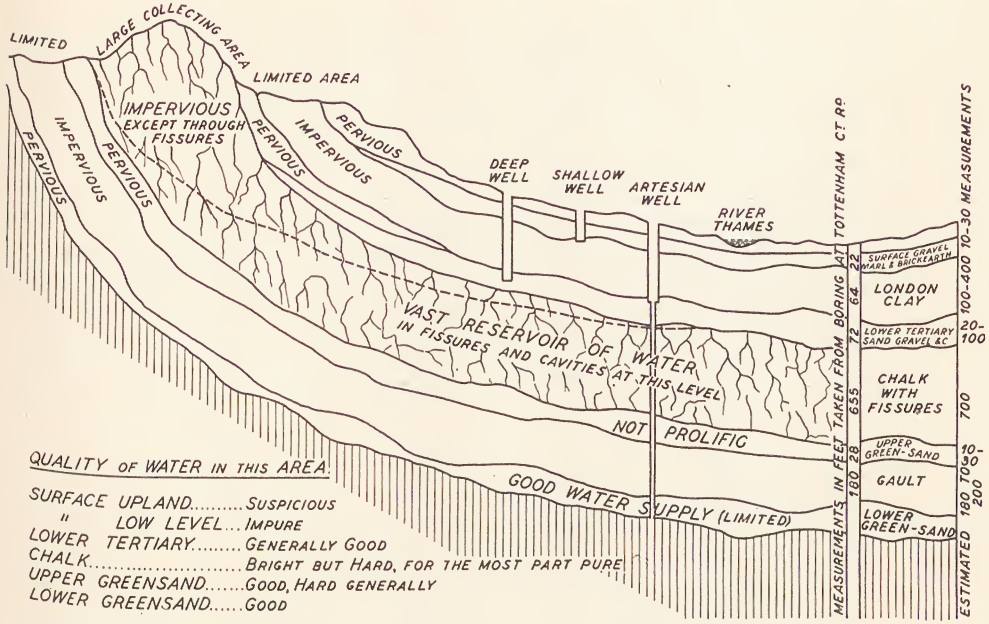


Fig. 9.—A good example of an underground supply tapped by Artesian wells—the London basin

This is a naturally formed reservoir of chalk.

This basin extends a considerable distance, and the chalk outcrops, i.e. comes to the surface, in the Chilterns to the north and on the North Downs in the south. At these two points are the gathering grounds or catchment areas, where the rainfall percolates and ultimately finds its way to the basin referred to. The borings are usually made to a depth of 500 or 550 ft. The purity of the water is due to the long distance which it travels underground after it has been collected as rain. Reference has been made to treatment of the water in some instances ; this is because the hardness varies considerably, and in some cases is much less than would be expected from a chalk formation.

RAISING WATER

Various appliances are in use for raising water, and from the earliest times use has been made of the windlass and bucket. This method is still used in many parts where only small quantities of water are required at one time ; the question of cost, should the well be a deep one, usually prohibits the fixing of a pump for such places as a country cottage or group of cottages. In some parts even the windlass is not used, the water being drawn up by hand in a bucket attached to a chain or rope.

Pumps

These are of various types, such as reciprocating pumps, centrifugal pumps, and air lifts. The ordinary suction or jack pump is an example of the simplest type of reciprocating pump, giving a 25-ft. lift.

Lift Pumps

A lift pump may be either single- or double-acting, and will lift water above the level of the pump itself from 10 to 100 ft., according to the power available. A double-acting pump delivers water at each stroke, whereas a single-acting pump delivers only at alternate strokes. Where it is desired to lift water to heights of more than 100 ft. a force or plunger pump should be used. This type of pump has a solid piston or ram working through a stuffing-box.

Air Vessels

Every lift pump should be fitted with an air vessel on the delivery pipe close to the pump. This vessel acts as a cushion or buffer, helps to reduce shock, and smooths out the variation in delivery, so that the discharging water is kept in a more regular rate of flow. The air vessel can be of cast iron or stout sheet copper. Where a fairly large quantity of water is to be pumped, the use of double or treble barrels is recommended, as these make for more even working. These pumps are fitted with cranks opposed at 180° and 120° respectively.

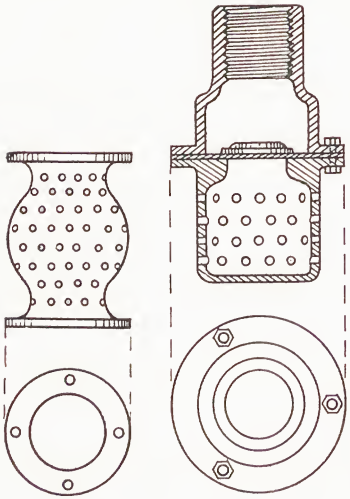


Fig. 10.—STRAINERS

Left: flanged strainer. Right: combined strainer and retaining valve with screwed thread for barrel. Note, total area of opening must be greater than internal diameter of suction pipe.

Foot Valve

The suction pipe should be fitted with a strainer, and in most cases a foot valve—the strainer to prevent matter which might prove to be a nuisance entering the suction pipe, and the foot valve to retain water in the pipe when the pump is not working.

Centrifugal Pumps

This class of pump consists of an impeller rotating within a fixed casing. They are of two main types: the turbine pump, in which the impeller is surrounded by fixed enlarging passages between diffusion vanes, and the volute pump, in which the impeller delivers directly to a spiral-shaped casing. These pumps

are smooth-running and reliable, they are quiet in action, and there are no valves to get out of order.

Air Lifts

These are often used for raising water from bore-holes. An air lift consists of two concentric pipes—the inner one being about 10 ft. shorter than the outer one—which are placed within the bore-hole so that the lower ends are well below the working water level. An air compressor supplies air to the space between the pipes; this air passes down to the water level, and a mixture of air and water is forced up the inner tube to the discharging end. The compressor, which is the only mechanical part of this outfit, can be placed in any convenient spot either near to or away from the top of the bore-hole. With the exception of the compressor there is very little to go wrong.

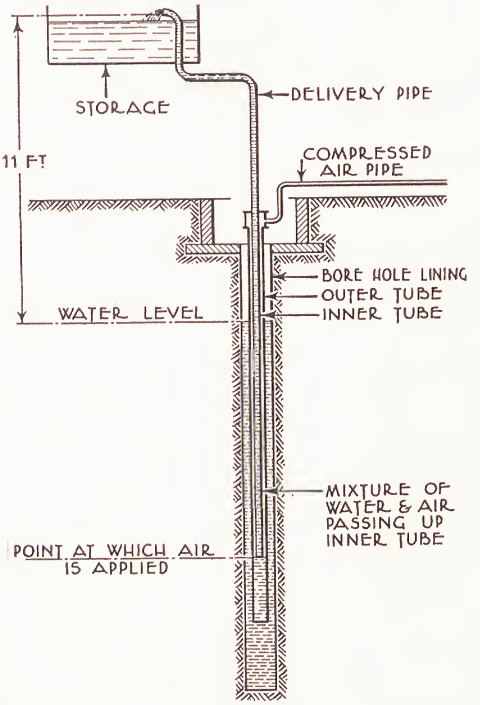


Fig. 11.—Diagram of arrangement of air lift

Compressed air is passed into the annular space between inner and outer tubes. Water is forced up inner tube until water level in outer tube sinks to level of bottom of inner tube. Air then passes up inner tube together with water, and this mixture, being much lighter bulk for bulk than water alone, a column much in excess of water can be supported by the air pressure available.

The Hydraulic Ram

This is a self-acting device used for raising part of the water which is supplied to work it. An hydraulic ram, when once fitted and started, will work automatically without attention, except for an occasional visit to renew the valves. The principle upon which it works may be likened to a water hammer ; as a flow of water is suddenly checked, part is arrested and passed into the delivery pipe, and part escapes either to waste or to be re-used for some other purpose. The diagram (Fig. 12) explains the principle on which it works. An air vessel is an essential part. The ram is a very useful device for raising water where the supply is plentiful. If there is an impure stream available as power, a ram may be obtained which utilises the impure water to raise water from a pure source without the two waters coming in contact.

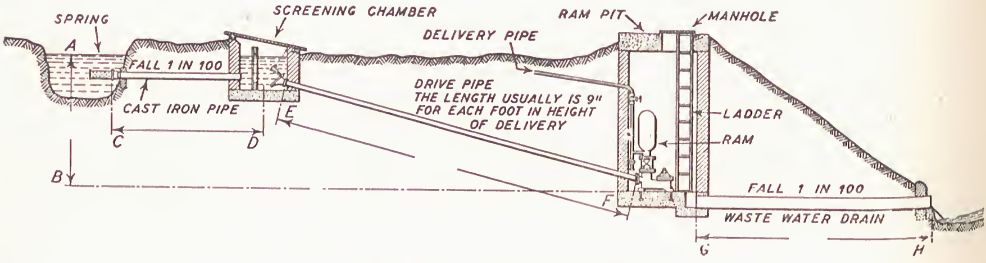


Fig. 12.—HYDRAULIC RAM

Showing method of installation affording protection of ram from frost.

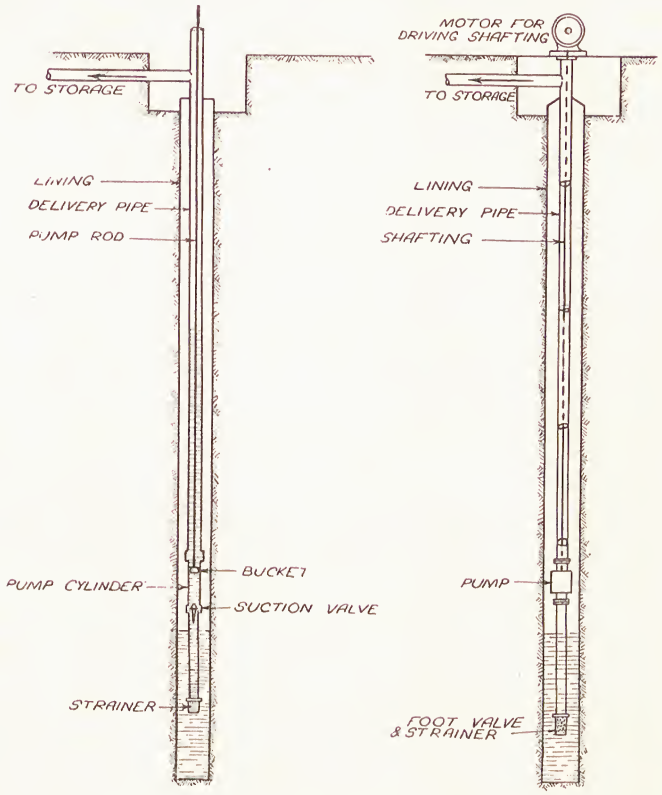
POWER FOR WORKING PUMPS

Where a supply of water is to be provided by pumping, due consideration should be given to the various methods available for operating the pump or pumps. The method to be adopted will be governed by several factors, such as the quantity of water required and the period over which it will be required, the availability or otherwise of a supply of gas or electric power, reliability and convenience of the apparatus, cost of fuel, the amount of attendance necessary, etc. The various sources of power may be summarised as follows: hand power, animal power, windmills, water engines, or machines; gas, oil, petrol, hot-air, or steam engines; and electric motors. Natural forces are often utilised as motive power, and the windmill comes under this head. As no fuel is required it is considered to be an advantageous method of raising water. In running costs the windmill is very economical, but is dependent upon sufficient wind velocity to provide the necessary movement. It is therefore necessary to provide ample storage capacity to guard against a spell of calm weather. With the use of power requiring fuel there are the advantages of convenience and reliability; it can be utilised as and when required, and if the plant is made automatic, the amount of attention necessary is reduced to a minimum. Where a definite quantity of water is required over given periods, the use of a fuel-driven pump is to be preferred for many reasons.

Hand Power

Manual labour for raising water may be utilised in many ways, and where hand pumping is carried out the type of apparatus provided will depend upon the depth of the well and the height to which the water is to be lifted. Ordinary jack pumps for shallow wells are usually operated by lever handles having a mechanical advantage of about 5 or 6 to 1. Where a lift pump is to be used, a wheel and proper gearing should be provided. At one time, hand power was the only means available in many outlying districts, because supplies of fuel for driving

an engine were difficult of transport. At the present time, however, road transport facilities are such that supplies of fuel are much less difficult to obtain, and the provision of a small fuel-driven pump or pumps should always be considered, and the use of manual labour employed only where small quantities are required or in areas where it is impossible to provide other means, but the latter are few and far between.



Reciprocating bore-hole pump. Centrifugal bore-hole pump.

Fig. 13.—ARRANGEMENT OF BORE-HOLE PUMPS

Animal Power

Deep-well pumps are sometimes operated by this form of power, a horse, pony, donkey, or mule, or sometimes an ox, being used for the purpose. The cranks operating the pump rods are connected by means of bevel gearing to a central spindle. The spindle is fitted with shafting according to the number of animals which are to be used (this may be from one to four), and a circular track is traversed by them, the diameter of the track varying according to the power required, an average being about 20 ft.

Water Power

Water power in the form of water-wheels, turbines, and water elevators is also used for raising water. Water-wheels are termed "overshot," "undershot," and "breast" wheels, according to the height at which the driving water is delivered on to them. Their action is dependent on the weight and pressure of water which enters the buckets or strikes the

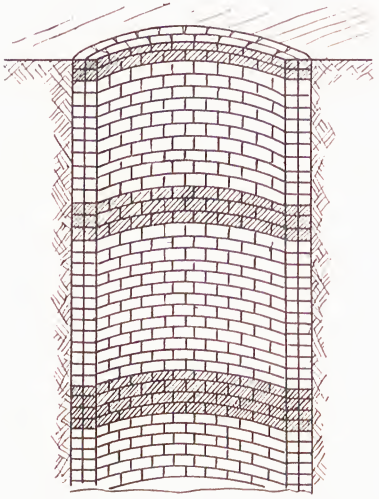


Fig. 14.—WELL OF BRICKWORK

Sectional elevation of dry steining with courses in cement at 3-ft. intervals.

floats of the wheels. Turbines are termed "inward," "outward," or "parallel," according to the manner in which water is delivered to them. They usually revolve in a horizontal direction, and they are operated by water impinging against the buckets or curved partitions in the revolving wheel. The disadvantages of water power lie chiefly in the fact that fluctuations of flow during a very dry season would fail to produce sufficient power to drive the apparatus, whilst in times of flood the water level may be too high to operate the apparatus correctly.

Fuel Engines

These are of various types, and there is a wide range from which to make a selection. The cost of fuel or electrical energy is often the deciding factor in the selection of a suitable plant. Where gas or electric power is available, a gas engine or an electric motor is usually decided upon. A gas engine is clean and efficient, and where gas is obtainable at a reasonable figure it is economical in running costs and requires very little attention after once starting up. Where town's gas is not available, a suction-gas plant could be used if desired. If a supply of electric power is at hand an electric motor is often selected; the plant is simple, efficient, and requires little attention, especially if the operation is automatic. Oil and petrol engines are extensively used, and have the advantage of being independent of any outside source of power such as gas or electricity; they may be obtained in many types to suit large or small duties. Steam engines are still extensively used for large plants where continuous pumping is required, and for this purpose they are eminently suitable; for small units where pumping is intermittent they are not much used, as the cost of firing and attention is too high in proportion to the work done. Steam engines are reliable, simple, have a long life, and possess the advantage of a range of power and speed which enables the rate of pumping to be varied.

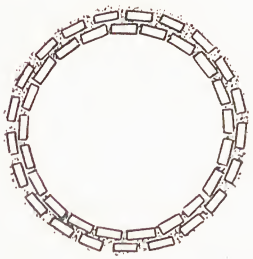


Fig. 15.—PLAN OF 9-IN. BRICK LINING FOR WELL

All bricks laid as stretchers and flushed up with fine concrete or cement mortar.

CONSTRUCTING A WELL

This class of work is usually left in the hands of experts, but it will be of interest to refer briefly to the method of sinking an ordinary type of well. In the first place, a great deal depends upon the formation of the ground, in which the well is to be sunk, as to whether lining is or is not required. In hard, rocky formations or in chalk the lining can often be dispensed with, excepting at the upper portion of the well, which should be lined as a protection against pollution.

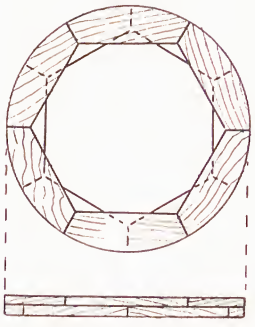


Fig. 16.—PLAN AND ELEVATION OF CURB

Brickwork Lining

If the well is to be constructed of brickwork, the bricks should be uniform in shape, hard, and well burnt. The thickness of the brickwork will depend upon the size of the well ; the method of laying is usually governed by the class of earth ; for instance, in stiff clay the bricks may be laid dry, and at intervals of a few feet four courses should be laid in cement mortar to act as binders and give strength to the lining (Fig. 14). Where the ground is unsuitable the whole of the brickwork should be laid in cement mortar, and the space between the brickwork and the excavation filled with clay puddle or concrete. This backing of clay or concrete must be carried down sufficiently far to prevent the entry of surface water into shallow wells. For deep wells, a watertight lining is also very necessary to exclude surface water, subsoil water, and any land springs that may be encountered. Small wells may be lined with 4½-in. brickwork, but for diameters of 6 ft. and upwards a thickness of 9 in. should be used and laid in cement mortar (Fig. 15). The lower portion is usually laid dry to permit water entering when the desired depth is reached ; in other cases, the whole of the lining is made watertight so that entry of water can take place only through the bottom of the well.

Other Methods of Construction

As an alternative to brickwork, concrete, stoneware, and iron pipes are used for the construction of wells. Iron pipes are especially useful where the land formation is of a very loose character, such as running sand, or where there is a possibility of land springs being met during sinking operations ; as already mentioned, these should be excluded from the well.

Methods of Sinking

Various methods are adopted for the sinking and lining of wells. One method for brick-lined wells is by the use of wood curbs. The excavation is made to a convenient depth so that support is not required

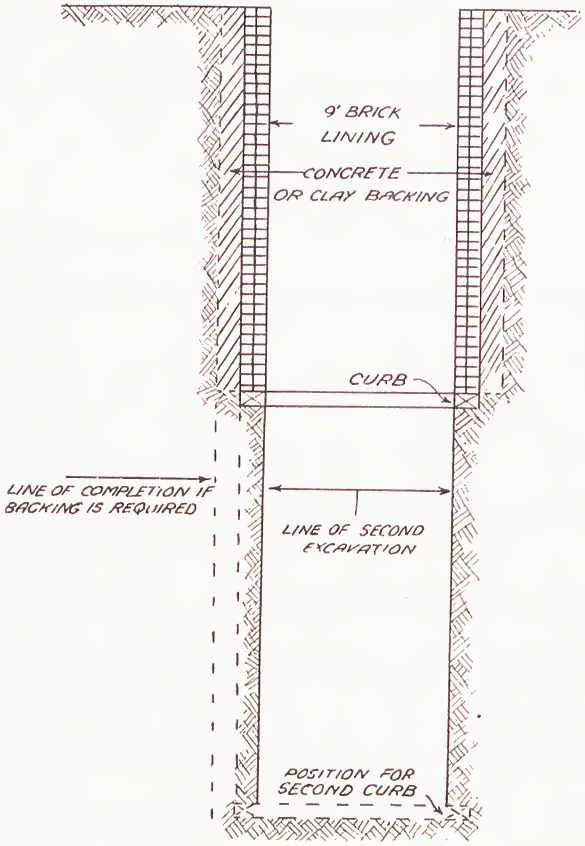


Fig. 17.—LINING WELL BY CURB PROCESS

in the way of timbering. In the bottom of the excavation is placed a curb or ring strongly made of elm or oak (Fig. 16). The internal and external diameters of the curb are equal to that of the brick lining.

The brickwork is next built up on this curb to ground level. This stage completed, the sinking is carried down below the curb but at a smaller diameter, so that curb and brickwork are supported by the earth beneath (Fig. 17). Now, if the well is to be continued at the same diameter as the brickwork already in position, the curb and brickwork must be supported to enable the excavation to be enlarged to the required size. This support is sometimes provided from the surface by means of iron rods or chains which are fixed to cross-stays placed beneath the curb so that the whole is suspended, leaving a clear space for the men to work beneath. Another method is by strutting from the bottom of the new excavation. When a further convenient depth has been reached, stout timber sole-plates are laid firmly on the bottom, and from these, struts are placed to support the curb and brickwork above. The remainder of the excavation is then completed; a second curb is placed in the bottom, and the filling of brickwork completed up to the under side of the first curb. These operations are repeated until the required depth is reached. The curbs may be left or, if desired, they may be cut out in sections and replaced by brickwork. At the surface, to prevent pollution, the brickwork should be carried well above ground level, and around the top of the well a concrete paving should be laid with suitable falls to conduct

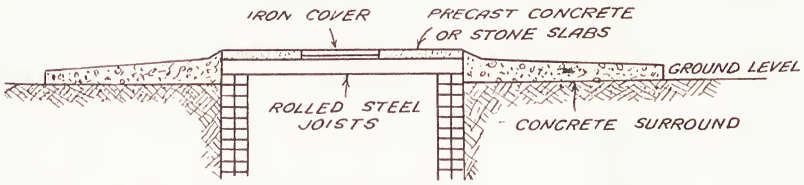


Fig. 18.—One method of finishing well at surface

surface water or splashings away from the well, and a proper cover of galvanised iron should be provided (Fig. 18).

Use of Trepan

This is a special type of tool, having steel cutting teeth, which is capable of boring a well up to 12 ft. in diameter, by a process similar to that employed for bore-holes, and has been used with success.

Pumping

During the sinking operations, precautions must be taken to keep the workings free from water, and as the work in hand is for the express purpose of obtaining a supply of water, it is obvious that water from some source or another may be reached sooner than expected. To cope with this possibility, efficient pumping apparatus should be provided which is capable of keeping the workings free from water, and it is advisable to allow a considerable margin for safety.

Safety of Workmen

No matter what type of tackle is to be used in the construction of the well, the general arrangement of the plant should be carefully planned so that materials and workmen may be lowered into the well or brought to the surface with speed and safety. Obstructions either within the well or at the surface should be avoided.

Completion at Surface

The method of completion at ground level will of course vary in accordance with the pumping arrangements to be provided. The gear may be fixed at the top of the well or in a pump house away from the well, but the chief precaution to be taken is to see that the contents of the well are kept free from pollution so that a wholesome supply of water is obtainable.

Bore-holes

Borings for water supply are formed mainly by two processes, rotary and percussion boring. The former consists of a drill and hollow boring rods which work round the circumference of the boring, the core, as it

is loosened, passing up into a core barrel which is brought to the surface at intervals. The latter method varies in its application, but, as its name implies, it consists in the main of crushing the ground by repeated blows from heavy tools, and loosening by various types of augers, the loosened material being brought to the surface from time to time by means of a hollow shell which is passed into the boring, the rods being withdrawn as often as may be necessary for the purpose of affixing the shell.

Lining

A permanent lining is necessary for a bore-hole, and this is usually formed of steel tubing having male and female screwed threads, and formed so that the exterior of the tube is quite flush. The lining prevents the entry of polluted water, and also gives support to the bore-hole. These tubes are lowered from the top as work proceeds, the bottom length having a special type of shoe to assist the pipes to sink.

Bore-hole Pumps

In addition to the air lift already referred to, bore-hole pumps of a reciprocating or centrifugal type are used for raising water. These pumps are lowered into the bore-hole for a considerable distance, according to the depth and water level, the driving shaft or pump rods being within the delivery pipe (see Fig. 13). These are suitable for wells of 25 ft. depth and over, and are obtainable with various diameter cylinders to meet the requirements of the particular installation.

YIELD OF ARTESIAN BORED WELLS

The following Table gives the amount of water that various borings are capable of yielding.

Diameter of Bore-hole in Inches	*Gallons per Hour*
3	300 to 5,000
4	400 to 6,000
5	700 to 8,000
6	1,200 to 10,000
$7\frac{1}{4}$	1,800 to 12,000
$8\frac{1}{2}$	3,000 to 15,000
10	5,000 to 18,000
$11\frac{1}{2}$	9,000 to 20,000
$13\frac{1}{2}$	10,000 to 25,000

(*Messrs. C. Isler*)

It is important to remember that a bore-hole should be started with a diameter of sufficient size to permit of completion with an even-size lining tube throughout.

USEFUL DATA FOR PUMPS, ETC.

It is easier to raise a given quantity of water with a double-barrel pump than with a single barrel (if the capacity of the single barrel is equal to both the double barrels). This is because the whole lift occurs at half the turn of the handle for a single-barrel pump, whereas with the double barrel it is distributed over both halves of the turn, therefore only one-half is lifted at a time. With a treble barrel the work is still further equalised, and the "dead" moment is avoided in the turn.

It is not desirable to use a pump with a smaller barrel than 2½-in. diameter, as the waterways are contracted. It is better to use a larger pump driven at a slower speed. The suction and delivery pipes should be not less than one-half the diameter of the barrel. Where the length is considerable a size larger should be used.

With large pumps or high-speed pumps it is advantageous to have a larger proportion of pipe area. The suction pipe should also be larger than the delivery, as in the former only the atmospheric pressure is available to overcome the friction, whilst in the latter the whole power of the pump is available.

SIZES OF SHORT SUCTION PIPES FOR SINGLE- OR DOUBLE-BARREL PUMPS

Diameter of pump barrel .	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.
,, ,, *suction pipe* .	1¼ in.	1½ in.	2 in.	2 in.	2½ in.	3 in.	4 in.

(1) Horse-power (h.p.) is equivalent to 33,000 lb. raised 1 ft. in 1 minute. A man's power is equivalent to approximately $\frac{1}{10}$ h.p.

Pump horse-power (p.h.p.) is the net useful work performed by a pump, and is equal to :—

$$\frac{\text{gallons per minute} \times 10 \times \text{the feet raised.}}{33{,}000}$$

Work done in raising water by pumping is calculated in foot-pounds, i.e. the pounds weight that can be raised 1 ft. high in 1 minute.

(2) In calculating the resistance to be overcome in raising water by pumping, (*a*) the height is the distance measured vertically from the surface of the water in the well to the highest point of delivery ; (*b*) the weight is equal to a column of water of the height given and of an area equal to the pump barrel.

Rule.—To find pounds to be overcome for each foot raised, square the number of inches in the diameter of the pump barrel and multiply by 0·34.

(3) To find the quantity in gallons raised per hour.

Rule.—Diameter of barrel in inches squared × 0·034 × length of stroke in feet × No. of strokes per minute × 60.

Example.—3-in. pump, 6-in. stroke, 20 strokes per minute. Required number of gallons per hour.

$\therefore 3^2 \times 0{\cdot}034 \times 0{\cdot}5 \times 20 \times 60 = 183{\cdot}6$ gal., theoretical quantity. For actual amount, deduct 20 to 25 per cent.

Lift and Force Applied to Pumps

All water is raised by "suction" until it enters the pump barrel, after which it is "lifted" or "forced" to a higher level.

The amount of lift in a jack pump is the distance from the top side of bucket when at bottom of barrel to the discharging nozzle, and this is equal to length of stroke.

In a suction and lift pump, the water is "lifted" to a height above the barrel, whilst in a suction and force pump the water is "forced" to a high level by a solid piston or plunger. In each type a retaining valve on the outlet of pump is necessary.

Single-acting pumps discharge water either on the up or on the down stroke, but not on both.

Double-acting pumps discharge water on both up and down strokes.

In the double-acting lift and force pump, water is raised by "suction" into the barrel; on the up stroke of plunger the water is "lifted," and on the down stroke is "forced" into the delivery pipe. It may be termed a combined suction-lift-force pump.

Tables of Approximate Quantities of Water Raised by Pumping

APPROXIMATE QUANTITY RAISED BY ONE MAN WORKING FOR 2 HOURS AT A FLYWHEEL PUMP WITHOUT GEARING

Height Raised in Feet	*Gallons Raised per Hour*	*Height Raised in Feet*	*Gallons Raised per Hour*
20	675	120	112
40	340	140	96
60	225	160	85
80	170	180	75
100	135	200	68

APPROXIMATE QUANTITY RAISED PER HOUR BY ONE ANIMAL WORKING 8 HOURS PER DAY WITH POLE GEARING

	Height Raised in Feet									
	20	40	60	80	100	120	140	160	180	200
	gal.	*gal.*	*gal.*	*gal.*	*gal.*	*gal.*	*gal.*	*gal.*	*gal.*	*gal.*
Horse . . .	4,200	2,100	1,400	1,050	840	700	600	525	465	420
Ox . . .	2,400	1,200	800	600	490	400	345	300	265	240
Mule or strong pony	2,000	1,000	665	500	400	335	285	250	220	200
Ass . . .	700	350	235	175	140	115	100	90	80	70

APPROXIMATE QUANTITY RAISED BY 1 EFFECTIVE H.P.
ALLOWING 33 PER CENT. FRICTIONAL LOSS BY GEARING, ETC.

Height Raised in Feet	*Gallons Raised per Hour*	*Height Raised in Feet*	*Gallons Raised per Hour*
10	13,200	120	1,100
20	6,600	150	880
30	4,400	180	734
40	3,300	200	660
50	2,640	220	600
60	2,200	250	528
80	1,650	280	470
100	1,320	300	440

NOTE.—Oxen walk at half to two-thirds the speed of a horse.

(*Hayward, Tyler & Co. Ltd.*)

Quality of Water

The quality of water which may be obtained from any of the sources mentioned is a matter of great importance. Many facts must be taken into consideration, and to ensure a wholesome supply it is often necessary to enlist the aid of the chemist and bacteriologist to determine the character of the water. The complete qualitative examination of water from the chemical and bacteriological aspect is beyond the scope of this article, but there are points of importance and interest which should be dealt with.

In the first place, the chemist and bacteriologist should work in collaboration ; the chemical examination alone is not sufficient to determine whether it is altogether a suitable water. Chemical analysis may show to be pure a sample of water which may, when subjected to bacteriological examination, be found to contain harmful bacteria which would render the water totally unsuitable. Chemical impurity cannot as a rule be detected except by analysis, and although the presence of certain impurities may be detected by appearance and taste, such as a water highly charged with iron oxide or mineral salts, it is the safest plan to submit samples for analysis.

Bacterial Pollution

This is quite a different matter from chemical impurity, as the water may contain disease-bearing bacteria of a highly dangerous character. This type of pollution may arise from various causes, and organic matter of animal and human origin may give rise to diseases such as cholera, typhoid or enteric fever. The carcasses of animals whose death has been caused by disease should be suitably dealt with by incineration or burial in quicklime ; putrefying carcasses on the land, especially in the vicinity of water courses, are a great source of danger. The drainage of farmyards, the presence of manure heaps, and collections of decaying vegetable

matter, are items which may cause pollution by organic substances. The drainage from isolated houses, the proximity of cess-pools and soak-aways, are also potential sources of danger. The foregoing sources of pollution give rise to the presence of bacteria or bacilli in the water, and this is regarded as dangerous when the number of *bacillus-coli* in a sample exceeds a determined limit. It should be remembered that, apart from the tests carried out by the chemist and bacteriologist, the source from which the water is obtained should be carefully inspected, and the possibilities of future pollution from any cause dealt with.

Sampling Water

Although certain simple tests may be carried out on the quality of a sample of water with the aid of test tubes and a few chemicals, it is much the better plan to leave the testing and examination in the hands of an expert chemist.

How to Take a Sample

The sample should be taken in a Winchester quart bottle, which should be sterilised and washed with distilled water. The ground-glass stopper should not be removed until the moment of taking the sample. Wash out the bottle thoroughly three or four times with the water to be sampled ; completely fill the bottle, replace the stopper securely, and cover it completely with a piece of clean linen or wash-leather secured around the neck of the bottle with string which should be sealed with wax. Particulars should be sent with the sample, giving : the date ; time of sampling ; nature of source (well, stream, tank, etc.) ; purpose for which water is required ; and possible cause of pollution, if suspected. These particulars are of great assistance to the analyst, and if the nature of the surroundings from which the water is derived is stated it will also be of great assistance.

Note.—If the sample is to be taken from a stream it should be taken well away from the banks. If from a tap, the water should be allowed to run for some time before washing and filling the bottle. If from a well provided with a pump, the latter should be operated to ensure that all water standing in the delivery pipe and barrel is pumped out. If the water is drawn by hand, the bottle may be lowered into the well in a wire cradle, or a clean pail may be used to draw the water which is to provide the sample.

ELECTRIC WATER HEATERS AND INSTALLATION

ELECTRIC geysers are little used for bath purposes on account of the heavy load required for good service. They are, however, available for hand basin and sink purposes.

They are highly efficient appliances. An important feature is that the water control must be interlocked with the electric switch, for if current is switched on without a flow of water the element will soon burn out.

As with gas geysers, the water temperature can be varied by varying the flow. The output of hot water at 150° F. with various loadings is shown in Table I.

TABLE I

OUTPUT OF HOT WATER AT 150° F. WITH VARIOUS LOADINGS

Loading in Watts	*British Thermal Units*	*Gallons per Hour at 150° from Cold Water at 50° F.*
1,000	3,412	3·4
1,500	5,118	5·1
2,000	6,824	6·8
3,000	10,236	10·2
6,000	20,472	20·4
8,000	27,296	27·3

It can be seen from the above Table that if a bath of, say, 10 gal. at 150° F. is required to be run off in 15 minutes a heavy load of 12 kw. would be necessary.

It is partly because of the heavy load required that the electric water heaters used for domestic supply are of the storage type.

STORAGE WATER HEATERS

Electric storage water heaters consist, in brief, of a hot-water cylinder, thickly lagged against heat loss, and provided with an immersion heater or heaters and a thermostat.

In recent years efforts have been made to standardise water heaters and, with this end in view, the British Electrical Development Associa-

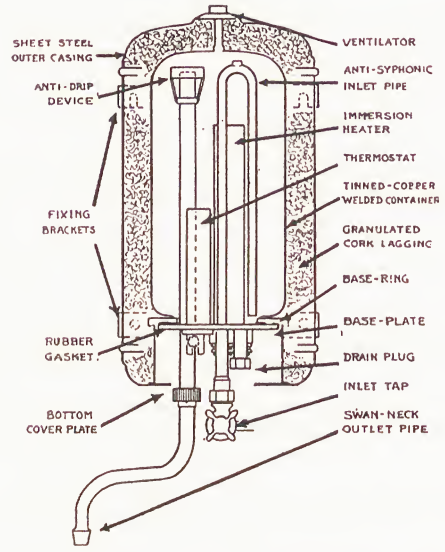


Fig. 1.—ARRANGEMENT OF A NON-PRESSURE-TYPE WATER HEATER (*Siemens*)

tion has issued recommendations to which the majority of manufacturers adhere.

There are, of course, many types of heater, but in general the salient points of the recommendations are maintained.

Construction

The inner cylinders or tanks are generally of welded-copper construction, with full-domed ends and tinned inside and out. In accordance with the recommendation issued by the water-heating committees of the British Electrical Development Association, they are tested to 50 lb. per square inch, except in the case of the cistern-type heater. Some manufacturers test to pressures as high as 120 lb. per square inch.

To the aperture at the bottom of the cylinder is bolted a plate. This plate carries all the working parts of the heater : it carries immersion heater, thermostat, and generally inlet and outlet pipes. With this arrangement the whole of the apparatus is removable for de-scaling.

The joint between plate and cylinder is made with a gasket—no red lead or jointing compound is used. Three starting screws are provided which enable the plate to be removed easily. A drain plug is also provided.

The lagging is invariably of granulated cork, and the thickness varies with the size of water heater ; sizes from 3 gal. up to 12 gal. capacity generally have 2 in. ; 12 gal. and over, 3 in. or more. The smallest size, 1½ gal., has only 1½ in. The outer casings are of sheet steel, treated internally to prevent corrosion and condensation, and finished externally in white enamel.

From this description it is clear that water heaters need careful handling, as the outer casing easily dents.

Water Storage Temperature

In order that a maximum quantity of water may be stored in minimum space, a storage temperature of between 160° and 190° is selected. The exact temperature depends upon the nature of the water, for the lower the storage temperature the slower the precipitation of scale.

With the higher storage temperature the quantity of water available

for use, when mixed with cold water, is almost double the nominal storage capacity.

Thermostats and immersion heaters will be discussed later; meanwhile the various types of heater are considered.

Types of Electric Storage Heaters

There are three distinct types: (1) Open-outlet or non-pressure type. (2) Pressure type. (3) Cistern type. Each has characteristics which render it most suitable for some particular purpose.

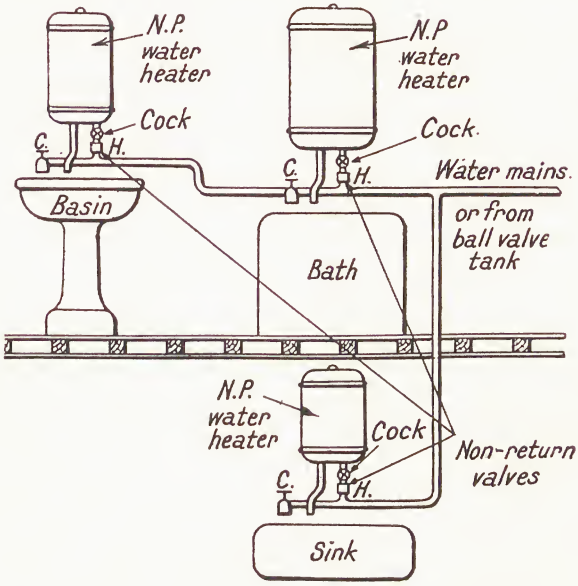


Fig. 2.—METHOD OF CONNECTION OF NON-PRESSURE OR OPEN-OUTLET ELECTRIC HEATERS

Note that this type of heater must be fitted over the point of supply and is only for one-point supply, unless a swivel outlet is fitted.

Standard Sizes

The whole range of standard-size water heaters available, and the customary load, together with the time required for heating from cold, is shown in Table II.

TABLE II

STANDARD SIZES OF WATER HEATERS

Capacity in Gallons	*Loading in Kw.*	*Heating-up Time 50° to 150°, Hours*
1½	·5	1
3	·5	2
5	·5	3
12	1·0	3·5
15	1·5	3
20	2·0	3
30	2·5	3·5
40	3·0	4
60	3 to 6	3 to 6

NON-PRESSURE OR OPEN-OUTLET HEATERS

An open-outlet-type water heater is shown in Fig. 1, and the method of connection in Fig. 2.

Open-outlet water heaters must be fitted over the point of supply, and they are for one point supply alone. They can, of course, be used to supply two points when a swivel outlet is fitted.

Non-pressure or open-outlet water heaters are sometimes described as "push-through type," and that name describes accurately the method of operation.

Construction

It is seen from Fig. 1 that a tap is fitted only to the inlet ; the outlet, which is provided with a stand pipe and which runs to near the top of the cylinder, is always open, and must not be fitted with a control cock. The vent at the top is always open to the atmosphere, but in some makes is provided with a check or flapper valve. The purpose of this vent is to admit air and prevent spurting of water. With this arrangement it is seen that the cylinder cannot be run dry, neither can pressure develop within the cylinder.

The inlet is fitted with a baffle so as to spread the incoming cold water in a horizontal direction. This baffle materially assists in preventing mixing of cold and hot water within the cylinder.

Operation

When cold water is admitted by the opening of the control cock, it pushes the hot water up to overflow down the outlet pipe, and continues to do so until the cock is closed.

To the top or bottom of the stand pipe is fitted a siphon or some such device to prevent dripping during heating.

TABLE III

FIXING CENTRES FOR CYLINDRICAL WATER HEATERS

Capacity of Cylinder	*Approximate Weight Full in Pounds*	*Distance between Bolt Holes in Inches*		*Bolt Holes to take*
		Horizontal	*Vertical*	
$1\frac{1}{2}$	45	9	12	$\frac{3}{8}$ in.
3	75	9	12	$\frac{3}{8}$ in.
5	120	12	16	$\frac{1}{2}$ in.
12	210	15	24	$\frac{5}{8}$ in.
15	260	18	28	$\frac{3}{4}$ in.
20	360	21	32	$\frac{3}{4}$ in.

It will be remembered that in heating through 100° F. water expands by about $\frac{1}{20}$th of its volume. If, therefore, when the inlet cock is closed the cold-water level is at the top of the stand pipe, there will be continual dripping at the outlet during heating. The purpose of the anti-drip

devices, one type of which is shown in Fig. 1, is to draw off water to slightly below the top of the pipe. With the cap type the cold-water level is at the bottom of the siphon cap. The distance between the bottom of cap and top of pipe is equal to the increase in water volume due to heating.

Installing Non-pressure Heaters

All non-pressure water heaters are provided with wall brackets, and in all well-known makes the horizontal and vertical distances between bolt holes are alike.

The fixing centres for cylindrical water heaters recommended by the British Electrical Development Association are shown in Table III.

It is seen from that Table that some of the larger sizes are too heavy to be fitted on partition walls; solid brick walls of 9-in. thickness will carry the largest water heater, but some reinforcing is necessary on walls of light construction. One method is shown in Fig. 3.

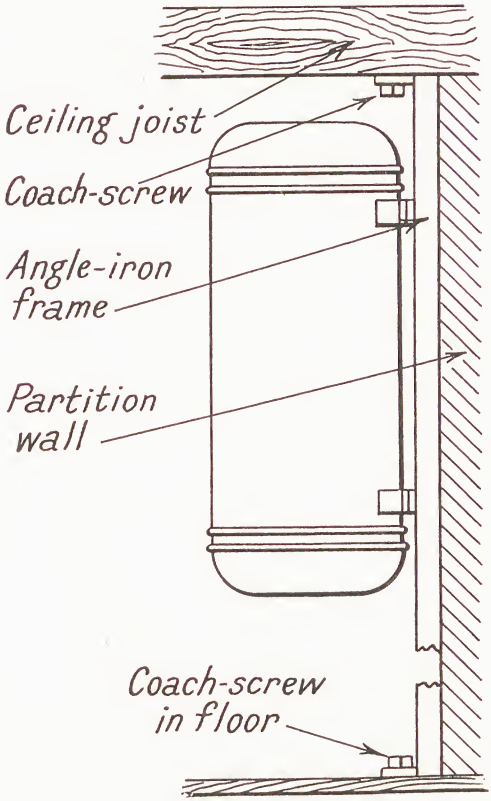


Fig. 3.—METHOD OF REINFORCING PARTITION WALL TO CARRY LARGE WATER HEATER

The top pair of brackets is always slotted on the under side. This permits bolts to be grouted into a wall and nuts placed upon the top pair, or if Rawlplugs and screws are used, the screws are screwed partly home. The water heater can then be hung without fear of slipping. The lower holes can then be marked off if not already made by template.

Pipe Work to Heater

When the heater is fixed in position the pipe work is commenced. This, being upon the cold-water side, is invariably in lead. Sometimes, however, where the feed is taken from a hot-water system, wrought iron is used or, occasionally, flexible metallic pipe.

Control cocks are supplied with a lead pipe liner upon which the joint is wiped, while at the other end is a T-joint, either wiped in the case of lead, or by an inserted T in the case of wrought iron.

Special connectors for insertion at the back of a tap, as shown in Fig. 4, are often used.

Putting Heater into Operation

When the pipes are connected up, the heater can be filled. On no account should the current be switched on before filling.

After the first heat up and when hot, all screwed and bolted joints should be tightened to take up any slackness brought about by expanding metal.

Careful attention to detail when installing non-pressure-type water heaters always pays, for, if badly installed, they can be a source of great annoyance.

Sizes of Inlet and Outlet

The inlet and outlet of such water heaters are of different sizes. In the absence of definite marking, they can be distinguished as shown in the following Table :—

TABLE IV

SIZES OF INLET AND OUTLET

Capacity in Gallons	*Inlet*	*Outlet*
$1\frac{1}{2}$	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.
3	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.
5	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.
12	$\frac{3}{4}$ in.	1 in.
17	$\frac{3}{4}$ in.	1 in.

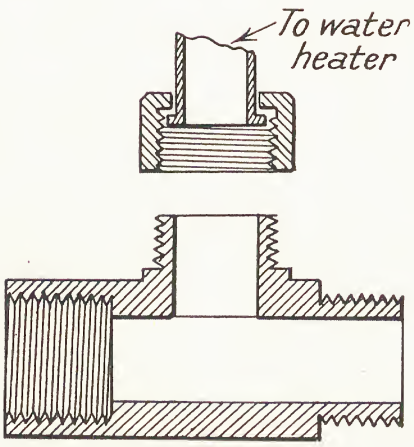


Fig. 4.—SPECIAL CONNECTORS FOR INSERTION OF PIPE TO WATER HEATER AT BACK OF TAP

Flooding and Spurting Troubles due to High Pressure at Inlet

The object of this difference in size is to prevent flooding of the air space which is normally above the water level, but, in spite of this precaution, high pressure at the inlet may still result in flooding and spurting from the top vent. Even if there is no spurting there is still flooding, and the whole of the water above the top of the stand pipe must be drained off after the cock is closed before water ceases to flow.

Cure for Flooding

The correct cure for flooding is to adjust the throttle at the inlet until an almost dead cut-off is obtained.

Cure for Spurting

The most common cure for spurting is to cap the top vent. Now while this cure is most effective it is often to the detriment of the heater, and one or both of two things result.

In the first place, water flooding up into the air space forces air out down the stand pipe. The moment the cock is closed, water commences to drain away from this space ; the outlet pipe is full of flowing water and air cannot, therefore, enter. The result is that what is normally an air space becomes a vacuum, and atmospheric pressure is, therefore, thrown upon the outside of the cylinder. This may ultimately result in the collapse of the cylinder.

The second result accruing from capping the top vent is that if the air does not escape through the stand pipe it becomes compressed by the incoming water pressure. When the cock is closed, the compressed air expands and drives water down the stand pipe at high velocity. The water delivered by a water heater is at a temperature of approximately 160° F., and high-velocity water at that temperature is apt to be dangerous.

Use Outlet Supplied with Heater

For the best results the outlet supplied with the heater should be used, and, as this is short, it involves fitting the heater close to the point of supply.

There is always a strong temptation to extend this outlet, but while an inch or two may make little or no difference, it must be remembered that, at the moment of closing the inlet cock, the outlet pipe is full of scalding water, and the longer the pipe the greater is the quantity which must be drawn off before flow ceases.

Neither must dips be allowed in the outlet pipe, for these dips form a trap in which water stays after draw-off and, when the heater is next used, the inertia of the trapped water may cause spurting at the vent.

To Supply Two Points

Non-pressure-type water heaters are often installed over a bath with a swivel arm to supply a sink.

Alternatively, the outlet pipe may be fixed and a change-over valve fitted as in Fig. 5. Where this valve is used it must be arranged so that one way is always open.

The practice of supplying a small basin from a large—say 12-gal. capacity—water heater should be discouraged, as the outflow of hot water is difficult to control. This will be realised if a little thought is given to the operation of non-pressure water heaters.

For this duty other types of water heaters are far more suitable.

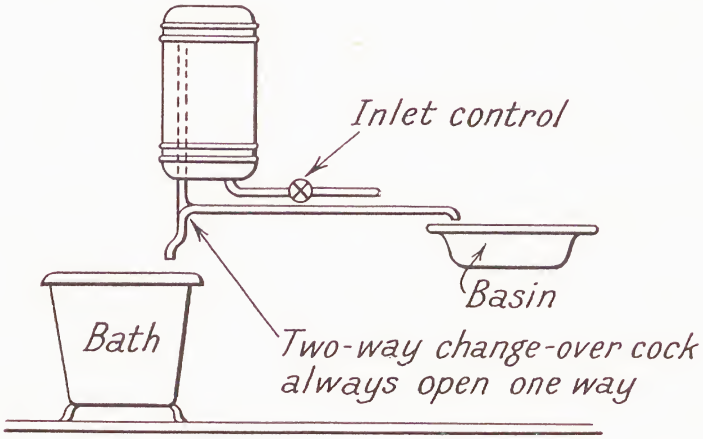


Fig. 5.—METHOD OF INSTALLING NON-PRESSURE HEATER TO SUPPLY TWO POINTS BY THE USE OF A CHANGE-OVER VALVE FITTED TO OUTLET PIPE

This valve must be arranged so that one way is always open.

Direct Connection to Mains

It is well known that water authorities legislate against the direct connection of hot-water equipment to their mains. They will, however, permit such connections, providing arrangements are made which, in the event of the mains water being shut off, prevent the back flow of hot water.

Such conditions occur in a non-pressure water heater if the control cock is opened when there is no inlet water pressure. These back-feed arrangements may be a non-return valve or a broken-feed device.

One type, shown in Fig. 6, is seen to consist of a double pipe ; water flows in the direction of the arrows. Air holes are provided at the top to guard against back siphonage. A broken-feed device is, of course, not required if a heater is fed from an overhead cistern.

Capacities and Applications of Non-pressure-type Water Heaters

Non-pressure-type water heaters with or without broken-feed devices are available in the following capacities :—

$1\frac{1}{2}$, 3, 5, 12, and 17 gal.

The most general application of the above heaters is :—

$1\frac{1}{2}$, 3, 5, wash basins and sinks.

12 and 17, for the supply of one bath.

Mixing Valves

In connection with the use of non-pressure water heaters over sinks and baths it should be remembered that the stored water is at about

160° F. Water at this temperature may crack a cold porcelain basin upon which it impinges.

Cold water should always be run in first or a special mixing valve used. Such a valve is shown in Figs. 7 and 8. It is seen that cold water from the mains flows partly into the heater and partly to the outlet. The result is mixed water at any required temperature at the outlet point.

Non-pressure-type heaters can be fitted below the point of supply (Fig. 9).

The working conditions of these heaters are exactly the same as for overhead type, except that the outlet is taken from the top. In some types a special control cock is fitted which closes both hot and cold water pipes. In this case a separate vent is run to prevent building up of pressure.

PRESSURE-TYPE WATER HEATERS

The next type of water heater is called a pressure heater. This name distinguishes it from the non-pressure type described. The pressure under which these heaters work is the static head due to an overhead supply cistern.

Pressure Head of Water Required

For ordinary domestic installations a head of 2 ft., or about 1 lb. per square inch, is a minimum for satisfactory service, except in cases where long horizontal pipes form part of the installation.

There is no difference in the design of pressure-type water heaters except that, in general, they are made for standing on floors. Because of this the elements and thermostat are fitted in a horizontal position near the bottom of the cylinder. With floor models the bottom outlet is omitted.

Using Non-pressure Heater for Pressure Supply

Provided that they are constructed to withstand the necessary pressure and have a connection at the top of not less than ½-in. diameter, all non-pressure heaters may be used for pressure supply, as in Fig. 10. Indeed, the 12-gal. size is frequently so employed.

Arrangement

The accepted meaning of the term " connected for pressure supply " is shown by the diagram in Fig. 11. From the water piping point of view it is seen to be identical with gas storage water heaters, or, if the boiler and primary flow and return of a coke system are omitted, identical with the rest of a dead-leg installation.

Now, whereas with non-pressure-type water heaters they must be fitted above the point of supply, a pressure-type water heater may be fitted above or below the service points and pipes connected thereto.

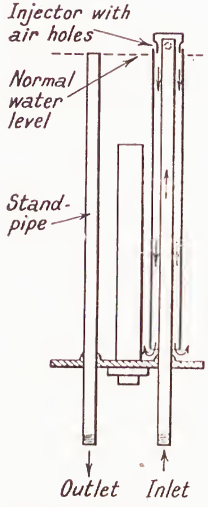


Fig. 6.—DIAGRAM OF BROKEN-FEED DEVICE TO ENABLE NON-PRESSURE HEATER TO BE CONNECTED TO MAINS

For electric water-heater installations the dead-leg system of pipe work is generally used. This is partly on account of the small heat input, but mainly for reasons of economy.

In dealing with medium-sized buildings with many draw-off points, it is obvious that if one large central storage cylinder is used, the necessity of drawing off a long length of pipe full of cold water becomes annoying. In order to avoid this the building is split up into sections, and storage cylinders installed in various parts of the building with dead-leg supply pipes.

Where Secondary Circulation Is Sometimes Employed

It would be wrong to say that the dead-leg system of supply is always used, for under certain circumstances, where pipes are exposed and can be well lagged, and current costs are low, circulating pipe work with central storage cylinders is sometimes installed.

These installations are, in the main, in districts where a restricted supply of current is offered at special low rates. They are not often used as domestic installations.

Elsewhere in this work, in the sections on hot-water supply, it is shown that in order to determine boiler capacity the hourly heat loss from the secondary circulation is calculated. If this loss was allowed to take place in an electric water heater system at ordinary current rates, very few people could afford to pay the resultant current bills for even a very small installation. Not only this, but the load required would have to be considerably increased in order to offset the heat loss.

Insulation of dead-leg pipes against heat loss is of little value unless the pipe is used, say, every five minutes or so, for within about 15 minutes stagnant hot water in pipes cools to a useless temperature.

TABLE V

STANDARD SIZES OF ELECTRIC WATER HEATERS

Capacity in Gallons		*Inlet*	*Outlet*	*Loading in Kw.*
5	Wall Type	½ in.	¾ in.	·5
12	Wall Type	¾ in.	1 in.	1·0
15	Wall or Floor Type	¾ in.	1 in.	1·5
20	Floor Type	1 in.	1 in.	2·0
30	Floor Type	1 in.	1 in.	3·0
40	Floor Type	1 in.	1 in.	3·0
50	Floor Type	1¼ in.	1¼ in.	3 to 6
75	Floor Type	1¼ in.	1½ in.	6 to 9
100	Floor Type	1¼ in.	1½ in.	9 to 12

Standard Sizes of Electric Water Heaters

The standard sizes of electric water heaters, together with heat input or loading, are shown in Table V.

Installing Pressure-type Water Heaters

The chief point to bear in mind in installing electric pressure-type water heaters is economy.

There is great economy resulting from the use of dead-leg systems, but such a system can also result in large losses unless care is taken with the installation.

Pressure-type electric water heaters can be installed in any part of a house, provided, of course, it is below the level of the supply cistern and pipes connecting to the service points. But the best position is close to the point of most frequent usage.

The reason for this is that when water has been drawn at a tap the connecting pipe is full of hot water at 160° F. which, as just stated, cools to a useless temperature in about 15 minutes. If such a pipe was, say, 15 ft. long and ½-in. diameter, and water withdrawn, say, twenty times a day, the loss in electrical units due to losses and cooling is about 1·5 units per day.

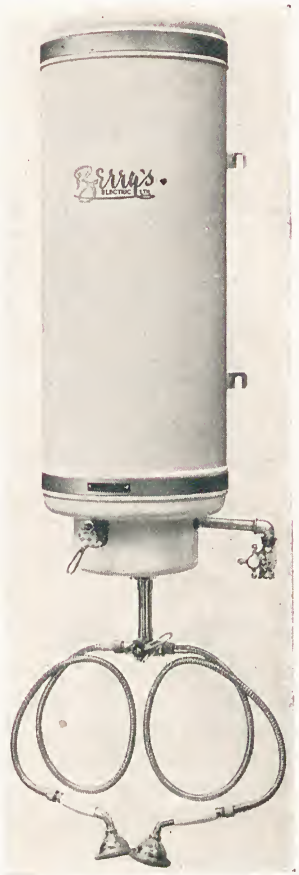


Fig. 7.—NON-PRESSURE WATER HEATER FITTED WITH CHANGE-OVER VALVE AND SPECIAL MIXING VALVE

Note the regulator on the left for regulating amount of hot and cold.

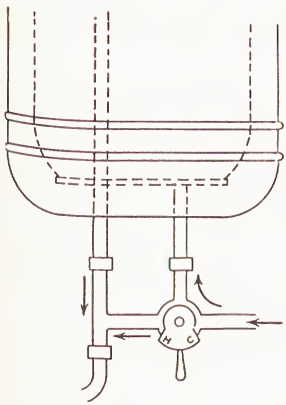


Fig. 8.—ANOTHER METHOD OF MIXING HOT AND COLD AT OUTLET OF NON-PRESSURE HEATER WITH SPECIAL VALVE

It is not possible entirely to eliminate this loss, but much can be done by installing the water heater close to the point of most frequent usage, which for domestic installations is always near a kitchen sink.

Feed Cisterns

Water expands by about $\frac{1}{20}$th of its volume when heated through 100° F. This means that there must be sufficient capacity above the cold-water level in the cistern and

Fig. 9.—NON-PRESSURE HEATER FITTED BELOW POINT OF SUPPLY

Pedestal of wash basin removed to show the electric storage heater. A "Reymez" wash basin. (*A. Reyrolle & Co. Ltd.*)

below the overflow to accommodate the increase of volume due to heating.

In many small installations the cold-water supply cistern serves also the water heater, but frequently a separate cistern is installed, and its capacity should be equal to at least one-and-a-half times the storage capacity of the heater. In the event of temporary water failure at the mains, it is always possible to obtain the full storage capacity of hot water with before-mentioned cistern capacity.

Pipe Work

The cold-feed pipe should project slightly inside the cistern to prevent the free flow of sediment into the pipe.

At the connection to the heater a cock should be fitted on the removable key type. A T-piece and drain cock with hose connection should always be provided, so that the heater can easily be emptied for de-scaling purposes or cleaning out.

All pipe work on the hot-water side should preferably be in copper tube with compression joints, for not only is the rate of loss from copper tube less than from wrought iron, but the absorption of heat by the metal of the pipe is less. Until the pipe itself has become heated hot water cannot be drawn at a service point.

It is well known that the loss of head due to friction in a copper pipe is considerably less than in wrought iron, hence one size smaller pipe may frequently be used without being detrimental to the flow of hot water. The smaller the pipe the less is the heat absorption and loss.

Pipe runs should be direct and as short as possible.

The expansion pipe should be not less than $\frac{1}{2}$-in. diameter and should, of course, be taken from the highest point of the system, and contain no traps or dips.

Installing in Flats

Now while the temporary failure of a cold-water supply is a rare occurrence, it must needs be guarded against when a number of water heaters are installed in a block of flats.

In Fig. 12 are shown four heaters connected to a common cold-water feed. It can be seen that if the cold-water supply fails and one of the

lower heaters is used, water to feed the lower heater is drawn from the upper heaters. In such installations a check valve should be inserted in each feed pipe.

The diagram also shows that a separate expansion pipe is required for each heater, for if all expansions are carried up as one common pipe, a circulating circuit may be completed, and also withdrawals from an upper cylinder could take place.

It was to obviate the need for running expansion pipes that the cistern-type heater, as considered later on, was developed.

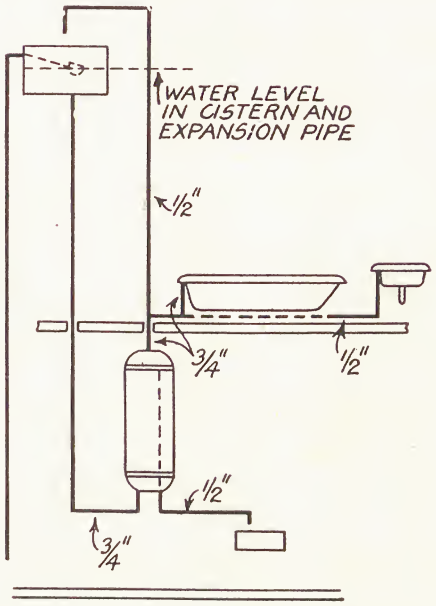


Fig. 10.—METHOD OF CONNECTING UP A NON-PRESSURE HEATER FOR PRESSURE SUPPLY

Provided the non-pressure heater is constructed to withstand the necessary pressure, and has a connection at top of not less than ½-in. diameter, it may be used for pressure supply as shown.

Combined Fuel-fired and Electric Systems

So far we have dealt only with pressure-type water heaters as separate installations, but a large number of heaters are installed for summer use alone, and thus have to work in conjunction with fuel-fired systems.

There is a variety of ways of arranging for this dual service, but whichever be used the main point to bear in mind is that under no circumstance should an electric water heater be allowed to circulate through pipe work.

A common way of obtaining a dual service is shown in Fig. 13. With this method it is seen that the main hot-water pipe is connected to the feed of the heater and there is an extra expansion pipe run. Now while the electric heater is fed with hot water from the boiler plant the electric heater must always be in use ; otherwise, if it is not, the whole of the water in the electric heater must be drawn off before hot is obtained from the other storage tank. It is better, therefore, to insert cocks as shown.

Electric water heaters are available, fitted with flow and return bosses for connection to a fuel boiler.

This type of installation has a twofold advantage. In the first place the heavy insulation on the storage cylinder gives a reduction of fuel burnt under the boiler, and also, if the fire is allowed to go out the electric heaters automatically come into action when the water cools. Such an installation can be used where rates for current are high, for the

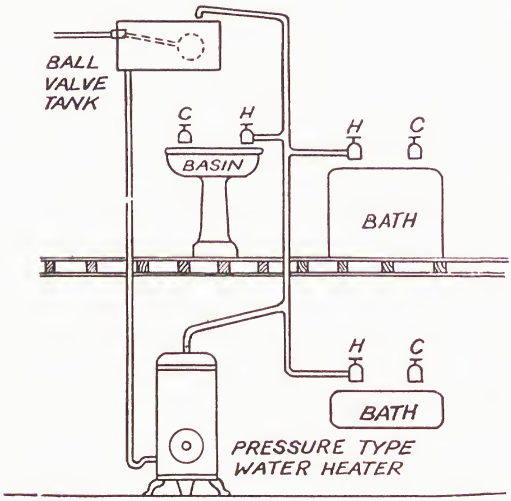


Fig. 11.—INSTALLATION DIAGRAM OF PRESSURE-TYPE WATER HEATER

Note that this type of electric water heater may be fitted above or below the service points and pipe connected thereto.

demand for electricity is only intermittent.

CISTERN-TYPE WATER HEATERS

The third type of storage water heater is known as the cistern type. This heater may be cylindrical or rectangular in shape, and consists of a cold-water feed cistern and hot storage tank under one outer casing, as shown in Fig. 14.

It is seen that the top cistern has a half-sphere ball valve and overflow. Both these are, of course, subject to water authority regulations.

A feed pipe from the cold cistern runs down to the bottom of the hot-water chamber, while the hot-water outlet pipe projects upwards from the bottom.

Position

From the design of the heater it is clear that it must be fitted above the points of draw-off, which are fed by gravity, as in Fig. 15.

Now in all hot-water plant the rate of outflow from a tap is at exactly the same rate as the flow of water from the cistern into the storage vessel. To put it another way, the flow of water from a tap depends upon the vertical height of the supply cistern. With this in mind it is seen that the head in a cistern-type water heater is very small, and under ordinary conditions the rate of output of hot water would be very low unless assisted in some way.

To assist in delivery the stand pipe attached to the hot-water outlet is drilled and the output of water is partly by displacement and partly by gravity.

To Prevent Element from Being Run Dry

Unless some provision is made to protect the element, the drilled stand pipe may easily allow water to drain away. In order to prevent this, the element and thermostat, which are in a vertical position, are surrounded by an open-topped sleeve attached to the heater plate, but watertight at the bottom.

This separate compartment prevents element and thermostat from being run dry and permits the whole of the water in the storage tank to be drawn off. The whole assembly plate is shown in Fig. 16.

Cleaning Out Fur from Cistern Heater

The addition of this container with the flow of cold water into it means that the greater part of the fur precipitated by the water is in a confined space around the elements. Because of this, cistern-type heaters must be cleaned out more frequently than other types. The exact interval between "clean-outs" depends, of course, upon the quantity of water which the heater is called upon to supply, but as a guide, if a pressure-type heater requires attention every year, a cistern type supplying the same quantity of the same water would need to be opened up every nine months.

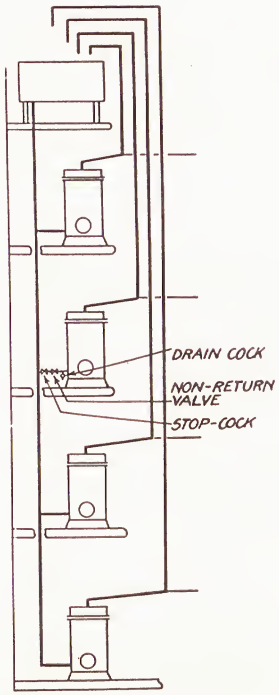


Fig. 12.—PRESSURE HEATERS IN BLOCK OF FLATS

To guard against hot water being drawn from the upper heaters if the cold-water supply fails, a check valve should be inserted in each feed pipe.

Adjusting Rate of Flow of Cold Water into Hot Tank

To the top of the inlet pipe is fitted a throttle which allows the rate of flow into the hot tank to be adjusted. By careful adjustment it is possible to arrange for the flow of water to be such that no matter how much water is in the hot chamber it is at approximately the same temperature. The rate of flow naturally depends upon the loading of the heater.

Selecting Cistern-type Heater

From a purely economical point of view it is best always to use a cylindrical heater, as for an equal water capacity the cylindrical water heater has less surface area than if rectangular. Selection is, of course, qualified by considerations of appearance and convenience. But the loss per hour—or, as is more commonly used, per 24 hours—from cistern-type water heaters is somewhat greater than from similar shapes of pressure or non-pressure water heaters. The responsibility for this rests primarily with the supply cistern. Theoretically, of course, the cistern contains cold water, but in practice this water becomes warmed by expanded water from the expansion pipe and contact with it.

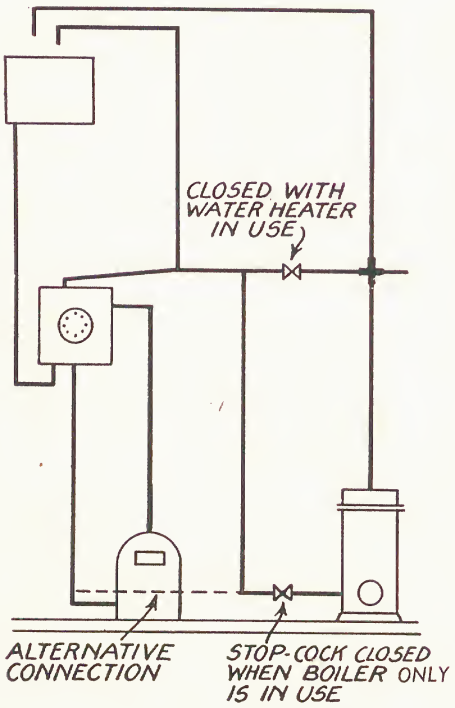


Fig. 13.—A COMMON WAY OF OBTAINING DUAL SERVICE

When electric water heater is not in use, valve in feed pipe is closed, and valve in horizontal pipe opened.

Installation of Cistern Heaters

Cistern-type heaters were primarily designed for use in flats to obviate the need for running an expansion pipe. Their installation involves only the tapping of the rising cold-water main or the cold feed to taps, and the remarks regarding the best position for pressure-type heaters apply equally to cistern type.

Cistern-type water heaters work on gravity. They must therefore be fitted above the highest point of draw-off.

As far as pipe work is concerned it is merely a matter of connecting the outlet to the supply points.

Because of the perforated stand pipe it is possible to supply hot water at taps level with the bottom of the heater, but, of course, under these circumstances the rate of flow gradually diminishes as the level of the hot water in the storage tank falls.

For the best results there should be not less than 12 in. of vertical height between delivery points and the bottom of the water heater, as shown by Fig. 17.

In fitting pipe work, a stopcock at the ball valve and on the outlet pipe is an advantage but not a necessity.

The most important point to bear in mind is that both heating elements and thermostat are withdrawable. The outlet pipe work should not therefore be installed so as to prevent easy removal, as is so often the case.

To Avoid Dripping at Overflow Pipe

On account of their convenience, cistern-type water heaters are often fitted in cupboards, and the overflow run through what may be a cold room. When this is done the overflow pipe should rise slightly. Such a procedure prevents constant dripping at the overflow outlet.

Dripping at the overflow is caused by warm saturated air from the supply cistern condensing its moisture in the cold pipe. With a slightly

sloping pipe the condensate runs back into the cistern, as shown in Fig. 19.

Ball valve and overflow are subject to the water regulations of the various local authorities.

HOT-WATER OUTPUT FROM ELECTRIC HEATERS

The type of water heater required for any purpose depends upon the number of points it must supply, and also upon the duty it must perform.

It is common practice to allow about 10 gal. per bath. Thus, to supply one bath a 12-gal. heater is required; to supply two successive baths 20 gal. are required, for it will be remembered that the recovery period from cold in a 12-gal. water heater is about three hours.

Partly on account of the absence of mixing of ingoing cold water with the hot in the tank, and partly on account of the automatic nature of the heating, a 20-gal. water heater with a loading of 2 kw. is found to be adequate for the needs of a small house where two baths are required per morning.

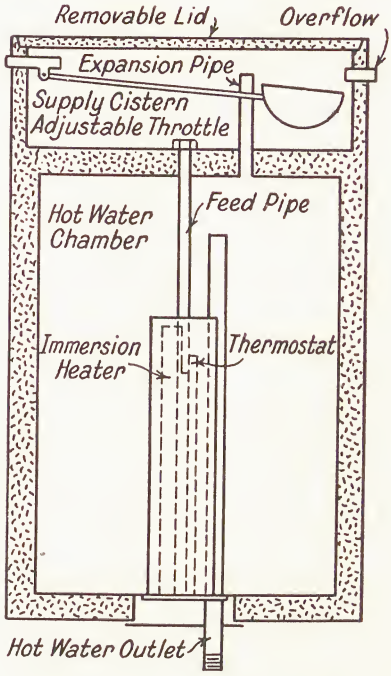


Fig. 14.—CISTERN-TYPE WATER HEATER

This heater may be cylindrical or rectangular in shape, and consists of a cold-water feed cistern and hot storage tank in one outer casing.

As soon as cold water enters a cylinder the thermostat comes into action, switches the heaters on, and reheating commences.

Electrical Connections—Important

In installing electric water heaters in bathrooms—a most common position for non-pressure and cistern-type water heaters—every care must be taken to see that the installation is in accordance with local water and electricity regulations.

The regulations issued by the Institution of Electrical Engineers which cover such installations, require that no switch be within reach of a person in the bath, and that all metal be earthed. This is to ensure safety, and if due attention be given to these points no installation can be deemed dangerous. Further, whenever possible, electrical conduits should be sunk in the wall or under floors.

In all water heaters there should be a positive metal bond between inner and outer case, otherwise the earth wire must be bonded firmly to both, for inner and outer cylinders are not necessarily connected together.

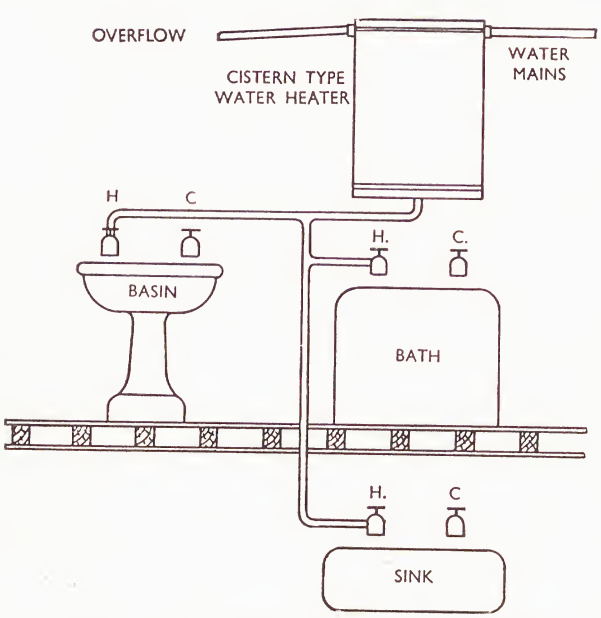


Fig. 15.—ARRANGEMENT OF CISTERN-TYPE HEATER

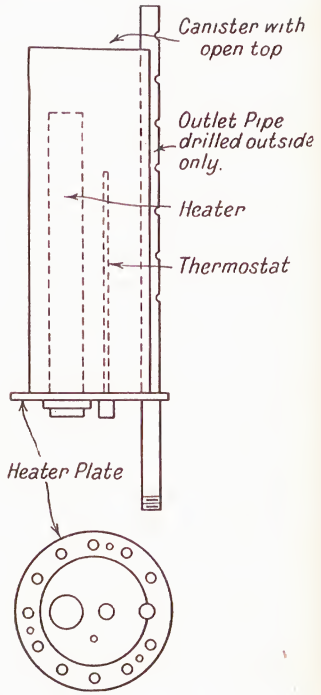


Fig. 16.—ASSEMBLY PLATE OF CISTERN-TYPE WATER HEATER

Showing heater and thermostat in compartment, and drilled outlet pipe.

Where lead-covered cable is used, that which incorporates an extra wire for earthing purposes is best, the earth wire being fixed as in Fig. 20.

Where metal tubing is used it must be secured firmly to the casing of the heater, and all fittings and joints scraped clean if the grip type is used. Exposure of the bare metal makes for continuity, and it is as important to have continuity in the metal conduits as in the conductors or cables.

Earthing Connections

The earth wire—a diagram of the earth circuit is shown in Fig. 21—may be connected by means of a clip to a main water pipe but not a down feed pipe from a cistern.

In view of the regulations, switches for water heaters should be situated outside the bathroom, and be double-pole type, with fuses.

AUXILIARY IMMERSION HEATERS

Both immersion heaters and thermostats are an important part of electric water heaters, but there is also a very wide field for their use as an auxiliary form of heat for fuel-fired systems.

When immersion heaters are fitted to a tank they can be used in con-

junction with or independently of the fuel boiler; they can be left entirely to the thermostat or they can be switched by hand. If left to the thermostat, and the boiler is lighted, the thermostat will switch off the heaters when the water is heated. The thermostat is a switch operated entirely by heat, and it matters little what is the heat source. Thus when a thermostat is installed, electric heaters are automatically switched on as the boiler fire dies.

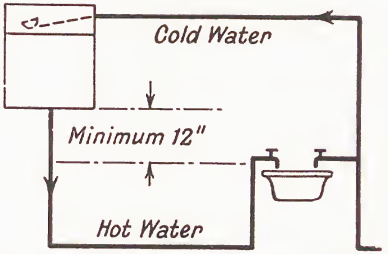


Fig. 17.—DISTANCE OF CISTERN HEATER FROM DELIVERY POINTS

For the best results there should be not less than 12 in. of vertical height between delivery points and the bottom of the water heater.

Automatic control of water heaters is secured by the use of thermostats. These are switches which are operated by heat. They are usually adjustable, and switch off the current supply when the water reaches the temperature at which the thermostat is set; they also switch on if water cools or if cold water enters the cylinder. The most suitable temperature difference between switching on and off is about 10° F.

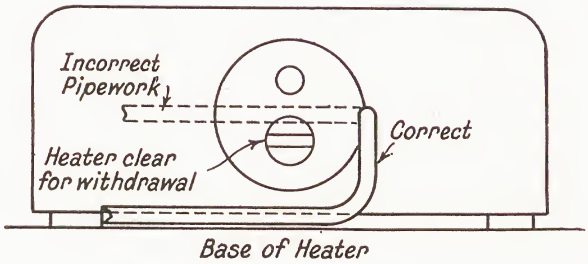


Fig. 18.—WHEN INSTALLING HEATER, ALLOW SPACE FOR WITHDRAWING HEATER AND THERMOSTAT

Note correct and incorrect positions of outlet pipe work.

Immersion Heaters

There are on the market many types of immersion heaters, but those best suited to domestic hot-water supply work are the withdrawable type. In this type the heating element is removable from its housing so that in the event of a failure replacements are easily made. The immersion heater tube or housing remains fixed in the tank or cylinder.

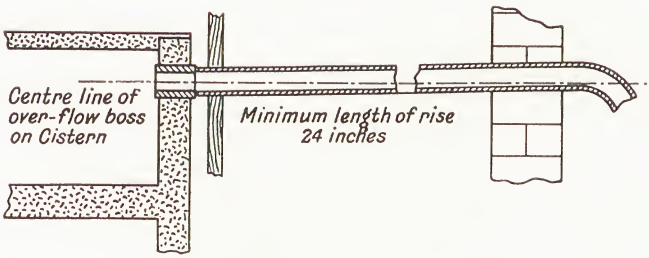


Fig. 19.—TO AVOID DRIPPING AT OVERFLOW WHEN PIPE IS RUN THROUGH A COLD ROOM, IT SHOULD RISE SLIGHTLY

One type,

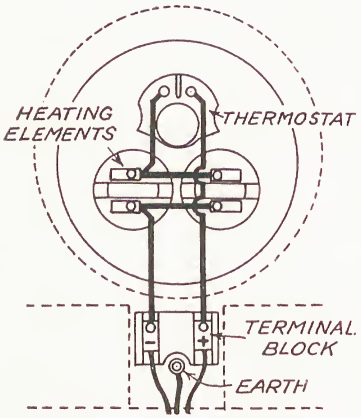


Fig. 20.—WIRING DIAGRAM OF ELECTRIC HEATER

Showing wiring up of two elements, thermostat and earth connection, using lead-covered cable which incorporates an extra wire for earthing purposes.

fitted with a flange, is shown in Fig. 22, and also one having a screwed boss.

If the purpose of the immersion heaters is to give a constant hot-water supply, thermostats should be fitted : if they are to be used only occasionally, then a three-heat switch gives good service. There is no point in fitting both.

Blade Type

Another type of immersion heater is the blade type as shown in Fig. 23. With this type high loads can be condensed into a more limited space, but it has the disadvantage of being non-removable unless the hot-water cylinder is drained.

The best type of immersion heater for hot-water supply purposes is that which has the greatest surface area, for the greater the surface the lower its temperature, and therefore the slower is scale formed upon it.

Position of Heaters and Thermostats

The blade type of heater can be fitted vertically or horizontally, but many standard withdrawable types are suitable only for horizontal operation.

When ordering immersion heaters the position should be clearly specified, as a heater unsuitable for vertical operation will have short life when fitted in that position.

The thermostat must be at a higher level than the heater.

Where heaters are fitted vertically from the top or bottom of a tank or cylinder the thermostat should be in a similar position, and the rod or heat-sensitive element of the thermostat be approximately as long as the heater.

Use of Circulators

Where heater and thermostat are inserted from the top of the cylinder, both should be as long as possible in order to heat the whole of the stored water. For this position circulators are more generally used, consisting of the element surrounded by a tube as in Fig. 24.

Heat Insulation

The importance of heat insulation cannot be overlooked. Standard water heaters are insulated with about 3 in. of granulated cork, but for insulating existing plant such material is not always available.

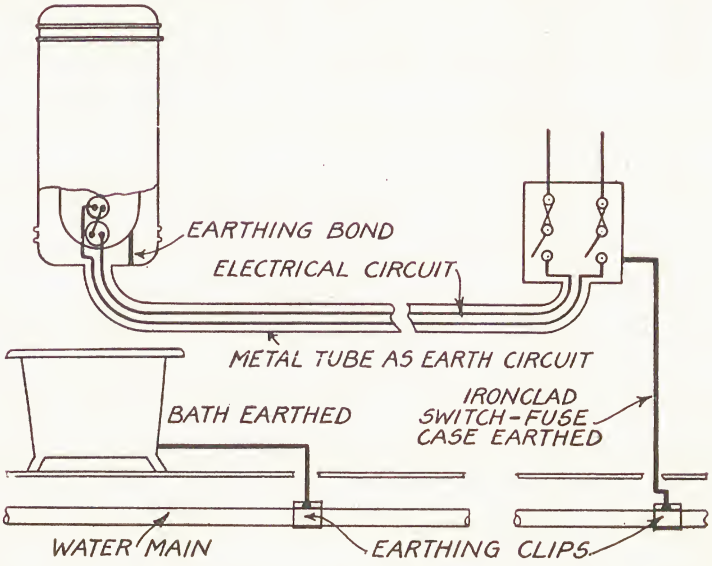


Fig. 21.—WIRING DIAGRAM OF THE EARTH CIRCUIT IN BATHROOM WHEN METAL CONDUIT IS USED

The metal tubing must be secured firmly to the casing of heater. All joints should be scraped clean of enamel if grip-type conduit is used. Note earthing clips.

Sawdust, slab cork, or asbestos mattresses are commonly used with or without a retaining cover ; on large cylinders plastic lagging is often used.

The following Table shows the approximate loss through 3 in. of different material for 100° F. temperature difference between faces.

TABLE VI

HEAT LOSS THROUGH LAGGING

Material	*Loss in Watts per Hour through 3 in. Thickness per 100° F. Difference between Faces per sq. ft.*
Asbestos	7
Cork	3
Sawdust	5
Soft Wood 1 in. thick	20

Loss from bare metal for 100° F. difference is approximately 45 watts per square foot per hour.

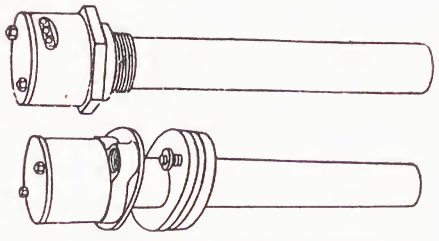


Fig. 22.—WITHDRAWABLE IMMERSION HEATERS FITTED WITH FLANGES

In these types, the heating element can be removed from its tube, so that in the event of a failure replacements are easily made without interfering with operation of the hot-water system.

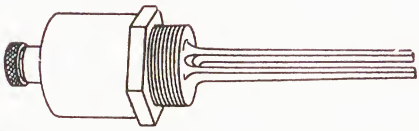


Fig. 23.—BLADE-TYPE IMMERSION HEATER WITH HIGH LOADING IN SMALL SPACE

The Immersion Heater Circuit

As with piping arrangements for pressure-type water heaters, immersion heaters should be fitted only to dead-leg systems. If they must be inserted in systems having a secondary circulation, then a valve should be inserted in the secondary return, as shown in Fig. 25. This valve should be closed only when the immersion heaters are the heat source.

Similar remarks apply to towel-rail circulations unless they come direct from the primary flow and return from the boiler, as shown in Fig. 25.

RUNNING COSTS

Typical Operation of a 20-gal. Heater

Results obtained with a 20-gal. heater loaded to 2 kw. are shown in Table VII.

TABLE VII

TYPICAL OPERATION OF 20-GAL. HEATER

Time of Withdrawal	*Gallons Withdrawn*	*Temperature ° F.*	*Time of Withdrawal*	*Gallons Withdrawn*	*Temperature ° F.*
7.30 a.m. .	10	170	1.45 p.m. .	2	167
8.00 ,, .	10	158	3.30 ,, .	2	169
8.15 ,, .	2	112	5.30 ,, .	1½	172
9.30 ,, .	1½	128	6.30 ,, .	5	173
10.30 ,, .	2	153	7.00 ,, .	4	172
11.30 ,, .	2	159	8.30 ,, .	2	170
12.30 p.m. .	2	163	9.30 ,, .	10	170
1.00 ,, .	3	165	10.00 ,, .	1	170

It is seen from the Table that some 60 gal. of water were withdrawn during the day. The total consumption of current during that period was 21 units. Thus the amount consumed per gallon of water at 160° F., which is the average temperature, inclusive of heat loss, was ·32 unit. The unit consumption at bath temperature of about 105° would be approximately ·16 unit per gallon.

Because of automatic control, the consumption of electricity in electric water heaters is almost proportional to the hot water withdrawn. A good

Fig. 24.—CIRCULATOR INSERTED IN TOP OF HOT-WATER CYLINDER

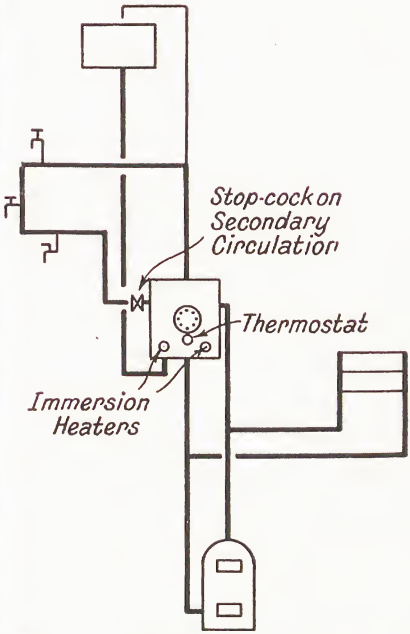


Fig. 25.—IMMERSION HEATER FITTED TO SYSTEM WITH SECONDARY CIRCULATION

average figure to use for estimating purposes is 4 units per 20 gal. at bath temperature if water is withdrawn frequently.

Consumption of 12-gal. Heater

If, on the other hand, a 12-gal. heater is called upon to supply only one bath of 10 gal. at 160° per day, the consumption in winter will be slightly higher, and can be estimated as follows :—

For example, the losses from a 12-gal. heater are about 8 units per week, while the units contained in 70 gal. of water at 160° F., with cold water at 45°, are 24, so that the amount per gallon—

$$\frac{(24 + 8)}{70} = \cdot 46 \text{ unit.}$$

It can be seen from the foregoing paragraph that the estimation of consumption for standard water heaters really evolves itself into estimating the probable consumption of water at 160° F. and multiplying by a factor of between ·3 and ·5, remembering that 10 gal. at 160° F. have the same heat content as 19 gal. at 105°.

The following Table shows the average number of units consumed by water heaters of various sizes.

TABLE VIII

AVERAGE NUMBER OF UNITS CONSUMED BY WATER HEATERS OF VARIOUS SIZES

Capacity in Gallons	*Units per Week*
30	115
20	85
12	60
5	35
$1\frac{1}{2}$	19

In considering unit consumption it should be remembered that if the heater is automatically controlled, the ultimate consumption is constant irrespective of load. The high load, however, makes available a much more copious supply of hot water, upon which it is but human nature to draw.

One further point relating to economy in operation is that in most houses there is a peak demand for hot water either daily or weekly. If the setting of the thermostat is adjusted accordingly, then the losses, which are, of course, proportional to the difference in temperature between water and air, are reduced.

Useful Formulæ

For the calculation of any of the quantities required in electric water heating, one of the following formulæ can be used :—

(1) Load required to heat any quantity of water in any given time :—

$$\text{kw.} = \frac{\text{gallons} \times \text{temperature rise}}{300 \times \text{time in hours}}.$$

(2) Units consumed in heating quantities of water

$$= \frac{\text{gallons} \times \text{temperature rise}}{300}$$

or $\qquad \text{load} \times \text{time in hours.}$

(3) Temperature rise per hour

$$= \frac{\text{load} \times 300}{\text{gallons.}}$$

CHURCH FITTINGS

IN preparing plans for work on fittings and furniture in various types of churches the architect should familiarise himself with the different formalities required to obtain the necessary approval of his designs before putting the work in hand. In some cases this will involve the preparation of special drawings and specifications and entail a certain amount of extra work beyond the plans required for the usual approval of the local authorities when the alterations or fittings come under the headings covered by local by-laws.

Church of England

Before fittings can be placed in or removed from an Anglican church an approval called a Faculty has to be obtained from the Chancellor of the Diocese. It is important that these preliminaries be observed or difficulties may arise later. The architect's plans are first submitted to the Parochial Church Council, and are then forwarded with a resolution of the Council to the body known as the Diocesan Advisory Board. These bodies were set up by the Archbishops at the time of the passing of the Ancient Monuments Act when churches were omitted from the Act on the undertaking that the Church of England would see to the preservation of its own property. The Advisory Board considers the suitability of the design and returns the plans endorsed with their approval, or their suggestions for revision, to the Church Council. It is important to bear in mind that the Board can only advise and cannot enforce their suggestions, and nothing prevents the Church Council from submitting the scheme to the Chancellor in its original form, but it is extremely unlikely that a Faculty will be granted for any scheme which has not received the approval of the Board.

Various legal forms have to be proceeded with and are best undertaken by a solicitor; on receipt of the Faculty the work can at once be put in hand.

The architect should include in his plan and specification all work which is contemplated even if the execution of it will extend over a period of years as, once the Faculty is granted, this can be carried out without further formalities provided that the original design is not varied.

Roman Catholic Churches

No formalities are required for fittings in these churches beyond the approval of the Roman Catholic bishop, and the local priest has wide

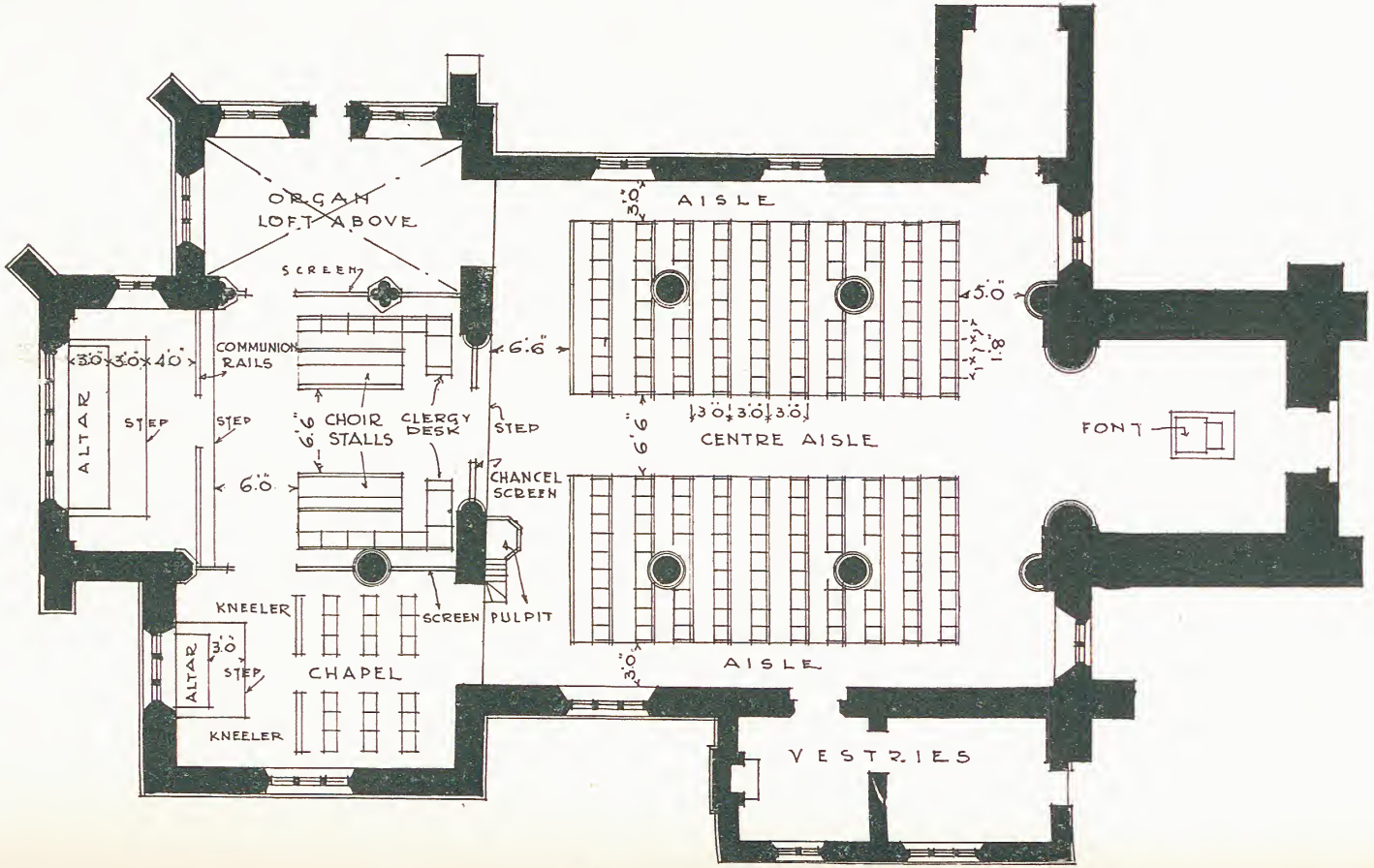


Fig. 1.—Layout of small church, with dimensions of seating

discretionary powers over the design of fittings for Roman Catholic churches.

Free Churches

As the name implies, no central authority has to be consulted for these churches, the whole of the responsibility resting with the governing committee appointed by each individual Church.

PEWS

The setting out of the pewing of a church should be arranged so as to avoid waste space, yet at the same time to allow means of exit for the congregation and the necessary manœuvring room for processions and other ceremonials (Fig. 1).

How Arranged

The centre passage up what is termed the nave should normally not be less than 5 ft. wide, and only in exceptionally small old churches where space is limited may this width be reduced to 4 ft. Side passages should never be under 3 ft. wide. When calculating the seating capacity of a large church it is well to remember that the ecclesiastical authorities will allow one row of chairs in a passage 6 ft. 6 in. wide, and two rows in one 8 ft. wide, and that these may be included in an assessment of the total of the building. All seats must face towards the altar, which is situated in what is generally defined by ecclesiastical custom as the east end of the church, no matter what the compass bearing actually is. When the passages or aisles have been set out, a space equal to the width of the central one must be marked off between the entrance to the choir and the first row of pews. Further cross-passages will be determined by the position of the various exits, but all must be wide enough to allow the congregation to leave without congestion.

Floors Supporting Pews

The floors of modern churches are usually of wood blocks, and even if the passages are paved in another material wood blocks should be used under the pewing.

On Stone Floors

In old churches, however, where the flooring is frequently of stone and is honeycombed with burial vaults, it is best to leave it undisturbed and to lay a flooring of joists and boarding about 3 in. high over the parts of the floor to be covered by the pews. The splayed oak cill to this floor running down the sides of the passages must be pierced for ventilation. Although in some churches the paving stones are laid on a thick bed of sand and are comparatively dry, in the majority they rest on the earth direct and are damp, therefore the joists and boards of the wood

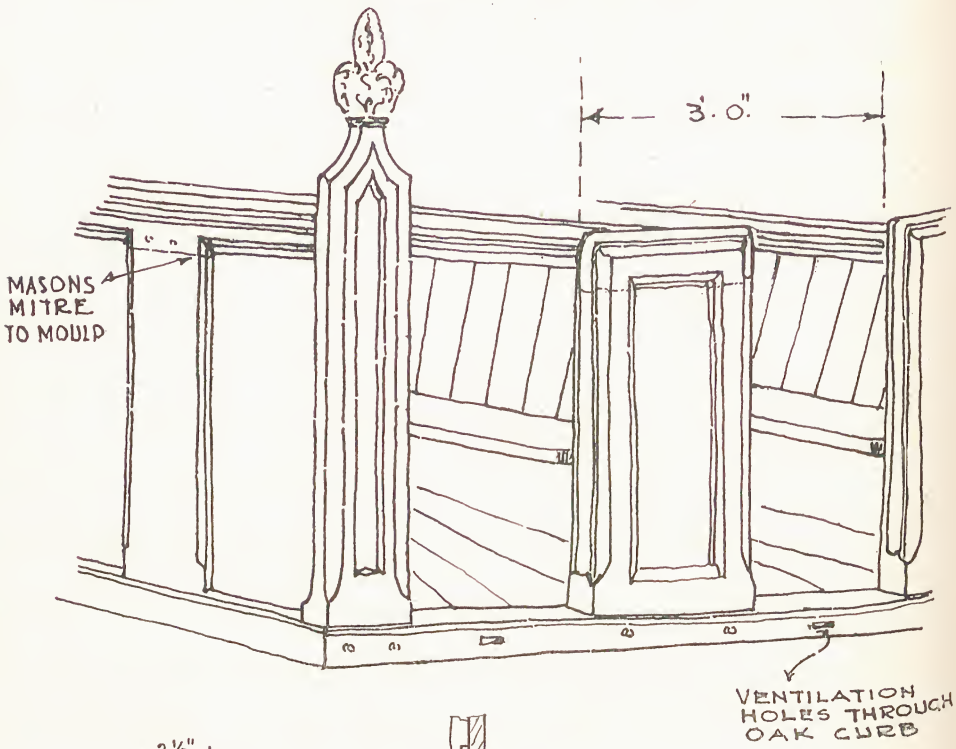


Fig. 2.—PEWS AND PEW END

Showing bench ends framed into curb of floor.

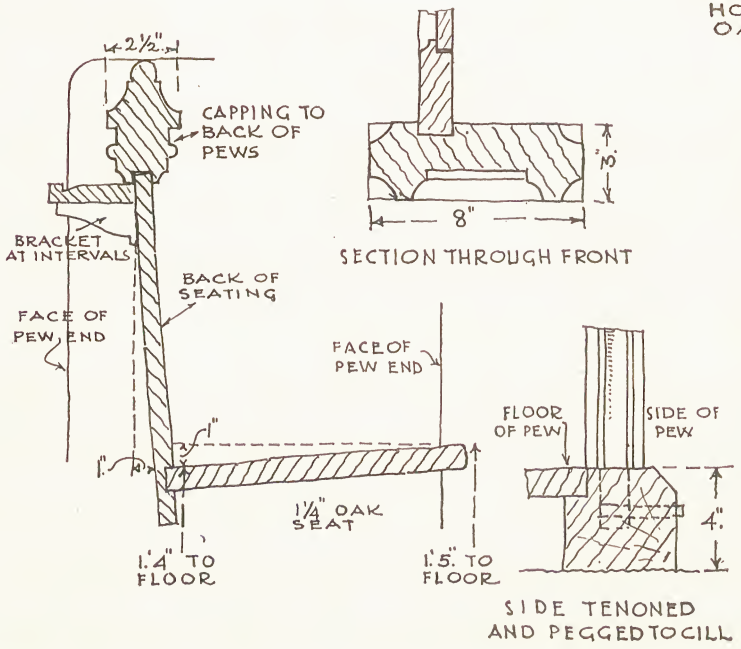


Fig. 3 (*left*).—DETAILS OF PEW CONSTRUCTION

flooring must be well creosoted as well as ventilated to avoid the risk of dry rot.

Spacing and Dimensions

The pews are spaced 3 ft. centre to centre. The front of the seat is most comfortable when it is 1 ft. 5 in. from the floor, sloping 1 in. towards the back (Fig. 3). Old pew seats are frequently narrow, seldom being more than 12 in. from the front edge to the vertical back board, but a modern seat should never be less than 14 in. wide and should have a sloping back. The height of pew ends and backs ought not to exceed 2 ft. 8 in., and the latter should never be continued down to the ground, but stop just below the seat, thus giving clear spaces under the pews for cleaning (Fig. 3).

In calculating the seating accommodation of a row of pewing, allow 1 ft. 8 in. for each person laterally, less the thickness of the pew ends.

Bench Ends

Where there is a raised floor the bench ends are framed into the curb, and as these ends have to carry the weight of the seat they should be of stout stuff, 2 in. in thickness being the minimum. Sometimes the ends are shaped and the moulded rail of the pew back is housed into them; at other times the moulding is mitred and continued as a finish to both end and back. Bench ends may be left plain or ornamented with carving; sometimes they are framed up and the panels decorated with applied tracery.

Seats and Book-shelf

Seats should be at least $1\frac{1}{4}$ in. thick, with a rounded nosing, and framed into both the bench ends and the backs and supported every 8 ft. Immediately under the capping of the pew back a small book-shelf should be provided. A kneeling-board is unnecessary and interferes with people passing along the pews; small hassocks, hanging on hooks to the lower edge of the pew backs when not in use, are all that is required.

CHOIR STALLS

Where the choir is accommodated at the east end of the church the seats, called stalls, are arranged in two rows facing one another on either side of the chancel.

General Arrangement and Dimensions

The general dimensions follow those of the pews, but the stalls should be raised on a platform about 3 in. above the chancel floor level. Old choir stalls were almost always considerably raised, the joists sometimes being carried on dwarf stone walls about 12 in. in height pierced

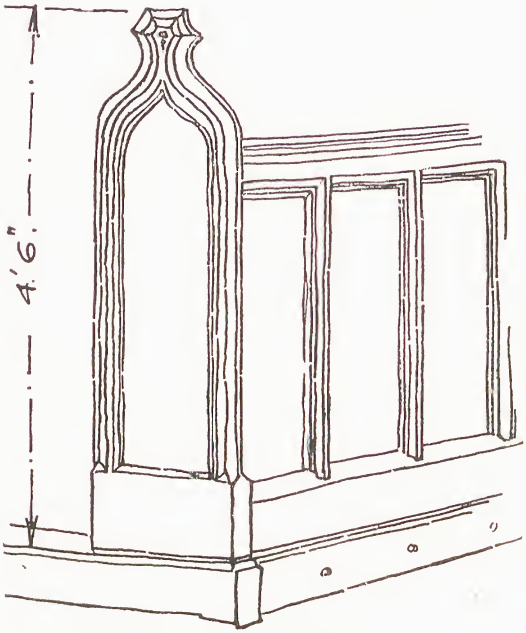


Fig. 4.—CHOIR STALL FRONT

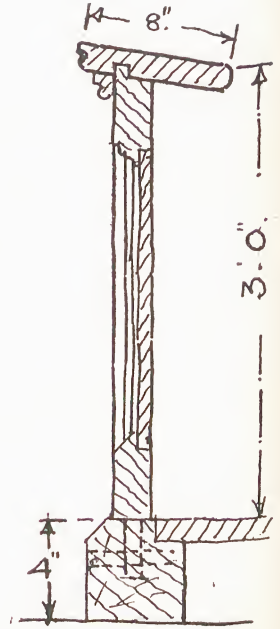


Fig. 4A.—SECTION OF CHOIR STALL, SHOWING BOOK-REST

in a pattern—a method probably adopted for acoustic reasons. Sides of stalls should be higher than pews, so as to allow the ends of the book-shelf to be framed into them at a convenient height for an adult to kneel and sing. These rests are 8 in. to 12 in. wide and 3 ft. 4 in. from floor, with a slight slope and framed into the ends of the front seats. The book-rest of the front row of stalls should not be higher than 3 ft., as these seats are occupied by boys (Fig. 4A).

Tip-up Seats

The old misericord or tip-up seats of mediæval churches are sometimes used in a modified form in modern choirs (Fig. 5). The main features of such a stall are the curved capping and the shaped divisions. The tip-up seat works in a quadrant sinking in the standard. When the seat is up a narrow projection gives support to a standing singer, and the curved capping is at a height to rest his elbows. The capping is deeply moulded where it projects forward between each seat, and the mouldings die away towards the middle of the semicircle, thus allowing a seated man to rest his head in comfort. The work in this type of choir stall is expensive, as all the mouldings are out of the solid and the scantlings of the parts are heavy ; cappings 4 in. to 6 in. deep at least, and the shaped divisions each out of 3-in.-thick stuff. Below the seat a solid blocking

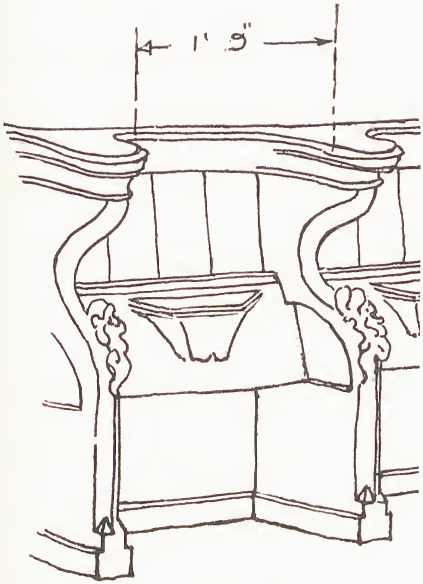


Fig. 5.—MISERICORD TYPE OF CHOIR STALL, WITH SEATS TIPPED UP

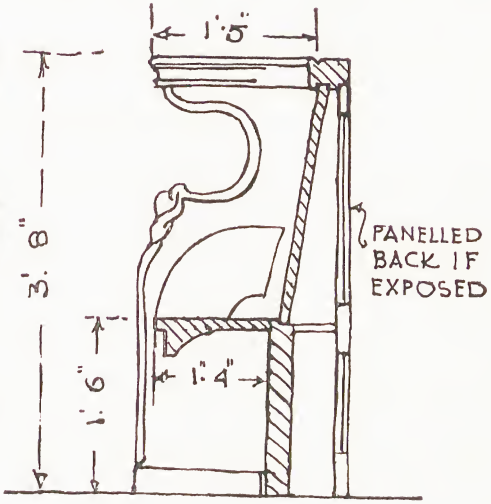


Fig. 5A.—MISERICORD TYPE OF CHOIR STALL
Showing section, with seat down.

is rebated between the divisions and to this the seat is generally hinged, but all misericords are frequently made with a peg hinge revolving in the divisions.

Clergyman's Stall

The clergyman's stall is a complete fitting, in modern churches placed immediately west of the choir stalls and in line with them. It should be 3 ft. 4 in. high, 2 ft. 3 in. wide, and have a sloping top 1 ft. 6 in. long with a beading on the lower edge to hold the prayer book. Beneath the top there should be a second

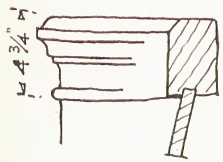


Fig. 5B.—TOP LAPPING TO MISERICORD CHOIR STALL

Fig. 5C.—SECTION OF DIVISION IN MISERICORD CHOIR STALL

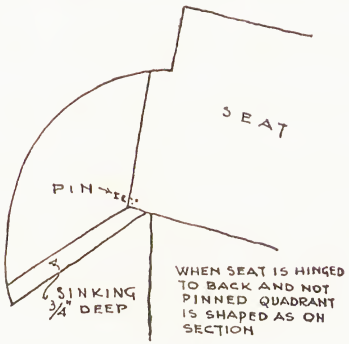


Fig. 5D.—MISERICORD TYPE OF CHOIR STALL
Showing quadrant sinking in divisions, in which seats revolve.

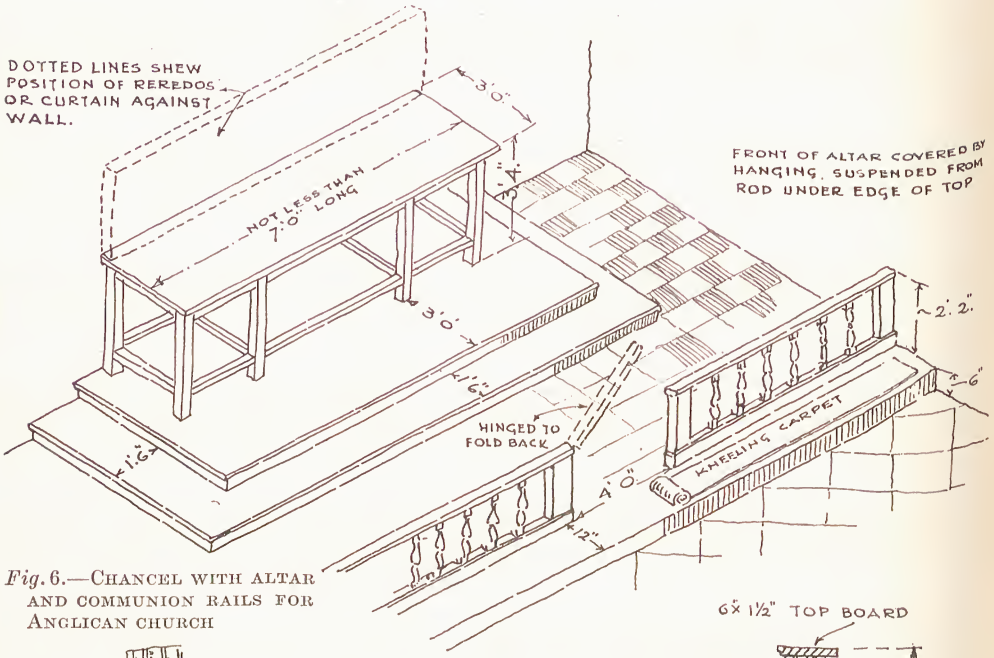


Fig. 6.—CHANCEL WITH ALTAR AND COMMUNION RAILS FOR ANGLICAN CHURCH

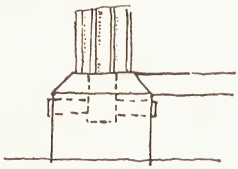


Fig. 7A.—FRONT OF END KNEELER SUPPORT WITH PEGGED TENON

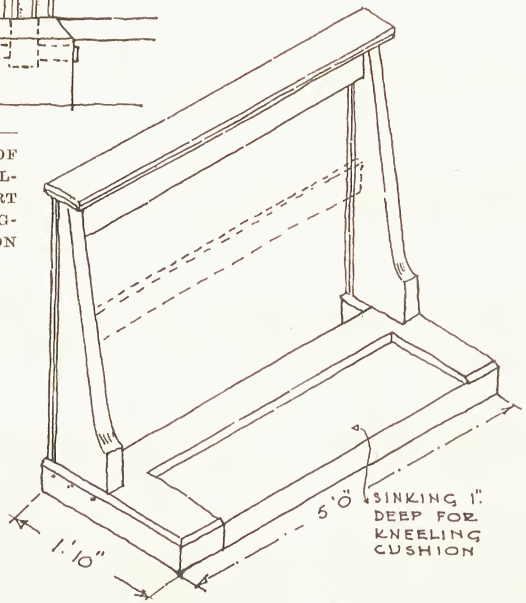


Fig. 7.—SIMPLE TYPE OF REMOVABLE KNEELER
When over 5 ft. in length, a second rail, as shown dotted, is required.

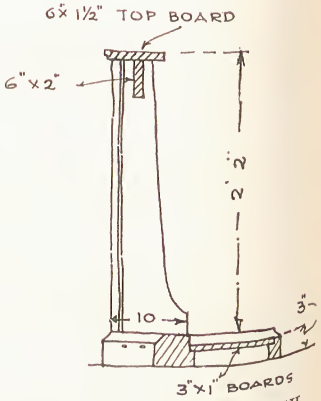


Fig. 7B.—SECTION THROUGH SIMPLE TYPE OF KNEELER

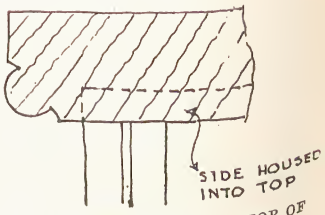


Fig. 7C.—MOULD TO TOP OF KNEELER

shelf for books. The ends of both the choir stalls and clergy desk may be ornamented, and the use of the poppy head is more suitable here than on the ends of the pews.

THE ALTAR

Formerly altars were made of stone, but since the Reformation are of wood. They may be entirely hidden by hangings (the most common practice), panelled solid on the front, or provided with ornamental legs.

The Important Dimensions

Whatever method of decoration is adopted, the following important dimensions must be strictly adhered to. The height is always between 3 ft. 3 in. and 3 ft. 6 in., and the width not more than 3 ft. (Fig. 6). Where there is an east window the altar should be as long as the cill above it; 10 ft. is not too long even for a small chancel 26 ft. wide. In no case should the main altar be less than 7 ft. long, though those in side chapels may be reduced to 5 ft. 6 in. by 2 ft. 6 in. front to back, the height remaining unvaried.

The top should be 1½ in. at least in thickness, and supported on eight legs if of a greater length than 7 ft. Where the legs are to be covered they may be a plain 3½-in. square with a 4-in. by 1-in. rail under the top, and another 6 in. above the ground rebated and screwed. The front and side edges of the altar top should be chamfered on lower edge and project 1½ in. in front of the legs to allow for the rod for the frontal or hanging, but at the back the altar top should be flush with the legs so that it may stand close against the wall.

Where there is no hanging the legs are designed in various ways and may take the form of a series of little arches or tracery carving, but the rigidity of the altar must never be jeopardised for the sake of decoration, and the top must be firmly screwed down to the frame in the same manner as a counter.

Altar on Platform

If the altar is raised on a wooden platform, this must project 3 ft. in front of it, and be never more than 6 in. in height. If more than one step is required each tread below must be 1 ft. 6 in. wide on both front and sides.

COMMUNION RAILS

These extend across the chancel in front of the altar. They should be 2 ft. 3 in. in height and set back 12 in. from the edge of the step which is usually placed in this part of the church, and a space of at least 4 ft. must be left between the rail and the lowest of the altar steps. The centre part of this rail must be made to open either as a counter flap or as a pair of gates allowing a clear space of 4 ft. wide.

Making a Kneeling-step

Where there is no chancel step a kneeling-step must be framed to the bottom of the rails, 6 in. high and 12 in. wide, and the whole securely fixed to the chancel floor.

The Rail

The top of the communion rail should be moulded to a shape resembling a bold handrail easy and pleasant to the grasp, and the balusters framed into it strongly, as the leverage is considerable when several people rise from their knees together. The practice of accentuating the sides of the centre opening by newel posts and of framing the rail into them is sometimes adopted as a means of gaining extra strength, but ecclesiastical authorities prefer a level top from end to end.

Movable Kneelers

Movable kneelers are sometimes required for temporary purposes (Fig. 7). These should be made as light as possible, but heavy enough to stand firmly without risk of overturning by a person pressing on them when rising. A length of about 5 ft. is most convenient, and if a longer rail is required this can be arranged by placing two or more kneelers side by side.

ROMAN CATHOLIC CHURCHES

The arrangement of seating follows very much the lines already described for Church of England buildings with one very important exception. In Anglican churches every effort is made to give the congregation an unobstructed view of the pulpit; in a Roman church this unobstructed view must be of the altar. To this end, side aisles with pews between the aisle and the wall should be avoided, and in small churches it is better to keep the aisles narrow passages and concentrate the seating towards the middle of the church. In larger churches this arrangement is often obtained by utilising the side aisles as chapels.

The Sanctuary

The sanctuary itself is often longer than in Anglican churches, as the choir is generally placed with the organ in a gallery over the west end. The sanctuary is raised one step above the level of the church and is cut off by communion rails; these are similar to those already described but are furnished with hooks on the inner side for the attachment of a cloth which is thrown over the top to hang down in front during the administration of Communion to the people. The space between the rails and the lowest step of the altar must not be less than 8 ft., and each step not less than 13 in. At the top of the steps the space in front of the altar must not be less than 3 ft. 3 in. from the nose of the step to the face of the altar, and this space should continue round the ends of the altar with a projection of 6 in.

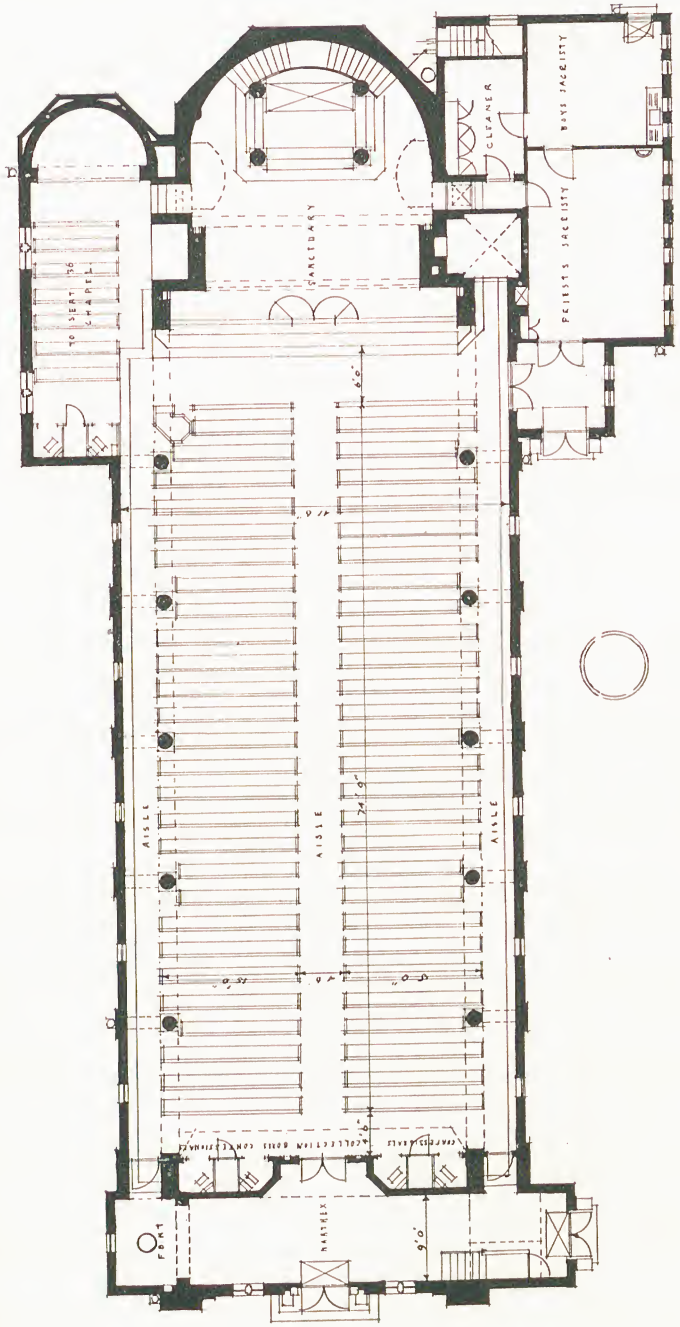


Fig. 8.—A Roman Catholic church, showing arrangement of fittings—St. Peter's (R.C.) Church, Dagenham

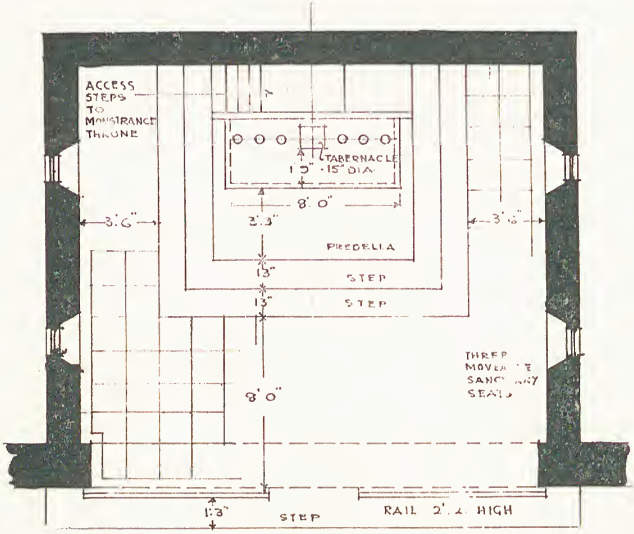


Fig. 9.—PLAN OF A SANCTUARY IN A ROMAN CATHOLIC CHURCH

The Altar

The altar itself must be of stone, which again differs from the Church of England usage where only wood is allowed. A minimum length is 8 feet and the depth from front to back about 3 ft., but the door of the tabernacle upon it must never be nearer to the front than 1 ft. 9 in. The edge of the altar top must overhang about 4½ in. in front, and this overhang may return round the sides as well. It is important that the altar be built on a solid foundation into the ground and it should be provided with a small cavity about 4 in. square in the top, covered by a stone, to contain a relic. The tabernacle must be not less than 15 in. in diameter if round, and this and the six candles dictate the minimum length of the altar top or mensa. The altar should not be placed close against the east wall, but far enough forward to allow a short flight of steps at the back to the monstrance throne which is situated immediately behind and slightly above the tabernacle.

The total minimum width of the sanctuary will be as required above with the addition of 3 ft. 6 in. between the lowest step and the north and south walls.

In a Roman Catholic church no other furniture is permanently placed in the sanctuary, but a sedilia consisting of three movable seats, or one wide seat with two stools, is placed against the south wall immediately behind the communion rail.

PULPITS

Both old and modern pulpits are sometimes found in stone, but wood was used in mediæval times and to-day is by far the most commonly employed material.

Position

The customary position of a pulpit in a church is immediately west of the chancel screen and on the north side of it, although in some very

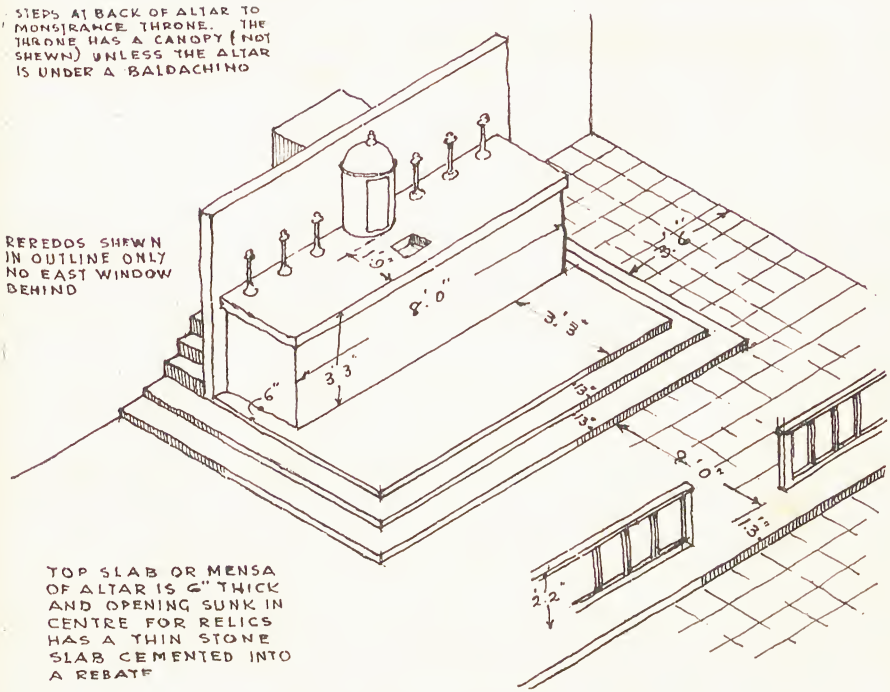


Fig. 10.—Sanctuary and altar of a Roman Catholic church

large churches and cathedrals, in order to ensure better hearing, it is moved farther towards the west end of the building ; the seating in these cases is generally provided by chairs which can be turned round.

The Sounding Board

In all lofty churches the pulpit must be provided with a sounding board, which is a large flat disc of wood framed up and finished at the edges with a cornice. Sometimes the sounding board is cantilevered out from a vertical panelled framing at the back of the pulpit, but usually it is suspended from the roof by a chain. Obviously, the method of construction will be determined by which of these two arrangements is to be adopted.

Dimensions and Shapes

Old pulpits were very small, usually between 2 ft. and 3 ft. in diameter internally, and noticeably high off the floor, as much as 4 ft. being common. The sides enclosing the preacher stood from 3 ft. 3 in. to 3 ft. 6 in. high, and were frequently octagonal.

Modern examples are more ample, and 3 ft. 6 in. to 4 ft. internal

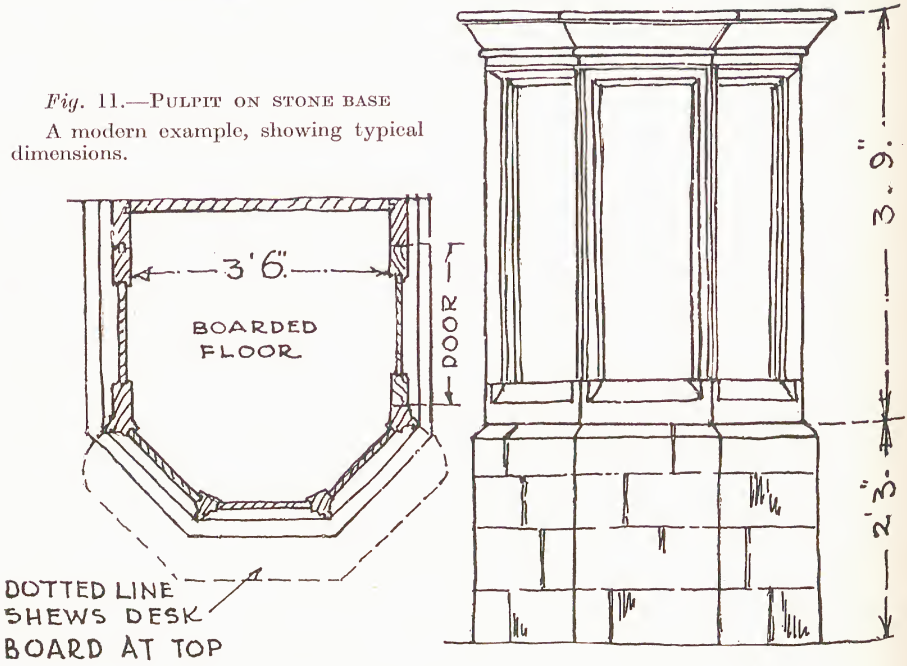


Fig. 11.—PULPIT ON STONE BASE
A modern example, showing typical dimensions.

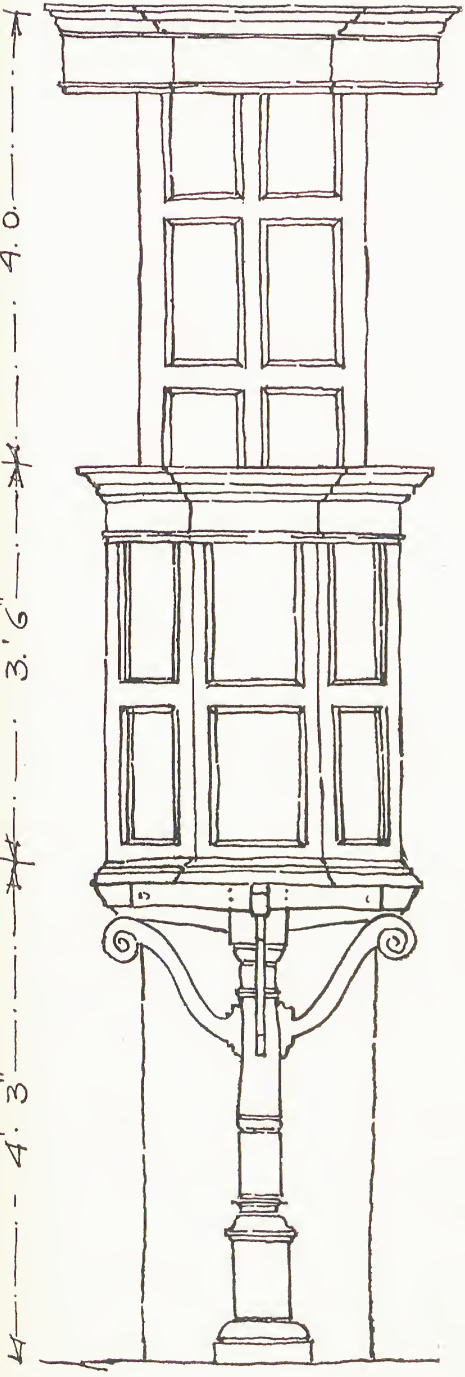
diameter is common (Fig. 11). While the height of the sides remains the same, the height above the floor is not more than 3 ft. 6 in. and sometimes lower.

Pillar Type

A good shape for a modern pulpit is five sides of an octagon, the remaining sides being taken up by a wall. One side panel at least must be made to open for a door. The pillar type is built up on a centre post with two main bearers at the top to take the floor, and subsidiary bearers framed into these and into a stout oak curb (Fig. 12.) On this curb the sides are built up, the members forming the angles of the octagon being tongued together and either left open or filled in with panelling. The constructive features are frequently hidden behind curved panels growing out of the centre part, and the whole is finished with a bold skirting.

Raised Rostrum Type

Another type of pulpit is constructed like a raised rostrum, being the same diameter to the ground, in which case the framing up is a comparatively simple matter. Frequently, however, the lower part below the pulpit floor is of stone, but a wooden floor must always be pro-



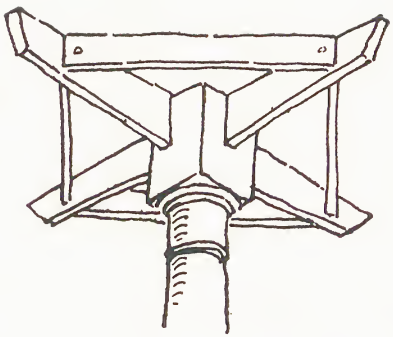


Fig. 12A.—Pillar-type pulpit

Floor framing at head of 6-in. by 6-in. post.

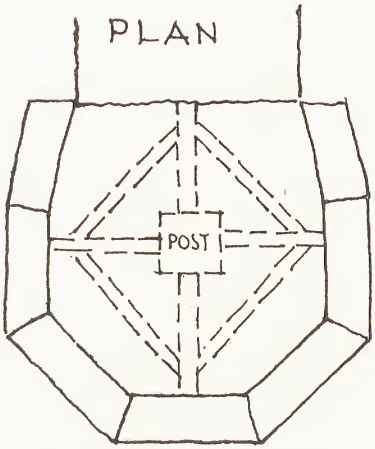


Fig. 12.—Pillar-type pulpit (from Wiltshire)

Built up on centre post, with two main bearers at top to take floor. Subsidiary bearers are framed into these and into stout oak curb, on which sides of pulpit are erected.

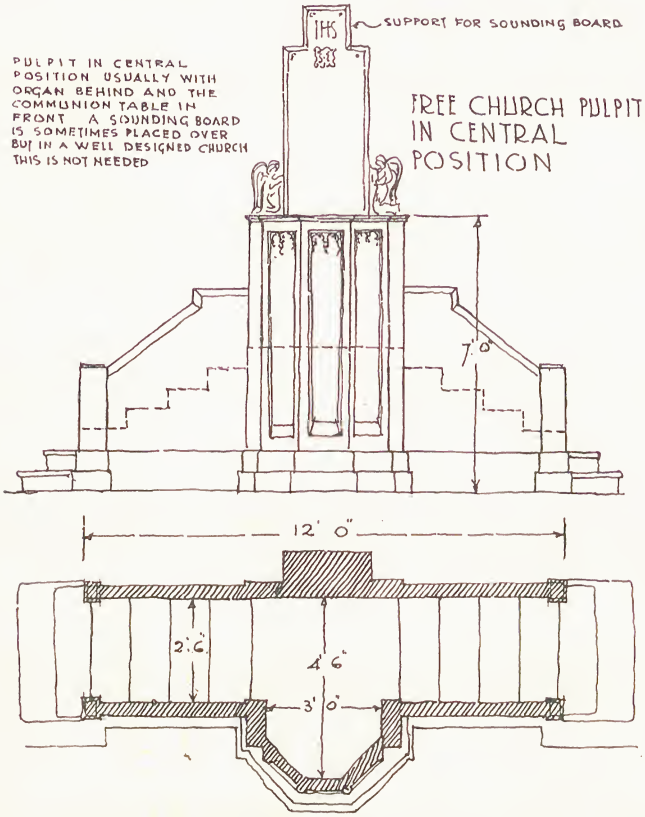


Fig. 13.—FREE CHURCH PULPIT IN CENTRAL POSITION

vided, or where this is not possible the stone platform must be covered with thick cork lino. The top capping member to a pulpit should be wide and flat in section so that a book can be safely laid upon it, and an adjustable desk is required in the side facing towards the centre of the church. A short flight of steps with a handrail should be placed in the most inconspicuous position.

Roman Catholic Pulpit

The pulpit is usually an inconspicuous fitting placed at one side of the church, but in small churches addresses are frequently given from the sanctuary steps and a pulpit dispensed with altogether.

Free Church Pulpits

In the Church of Scotland and the Free Churches the pulpit, on account of the greater stress on preaching, develops into an important fitting. The central position in which it is placed calls for a large-scale design of considerable interest. It becomes the focal point of the church and is frequently balanced symmetrically with two flights of stairs. The front of the pulpit may be richly carved and have a backboard and ornamental sounding board over, but this feature is not common, as behind the pulpit is a usual position for the organ and choir. Pulpits vary in size and are often of very ample dimensions, far larger than in many Anglican churches, at times approaching the appearance of a rostrum.

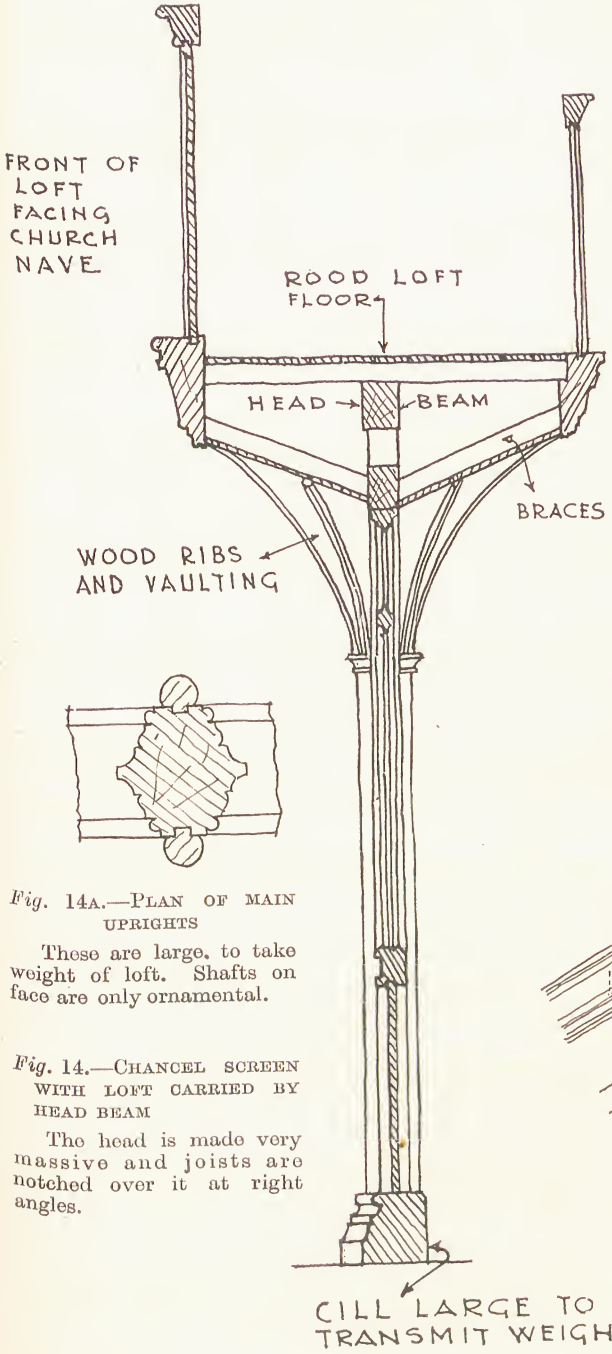


Fig. 14A.—PLAN OF MAIN UPRIGHTS

These are large, to take weight of loft. Shafts on face are only ornamental.

Fig. 14.—CHANCEL SCREEN WITH LOFT CARRIED BY HEAD BEAM

The head is made very massive and joists are notched over it at right angles.

THE CHANCEL SCREEN

Various parts of old churches were divided off by wooden screens, and those that remain are mostly very elaborately carved. The usual practice to-day is to have a division between the choir and the main body of the church called the chancel screen. This is fitted across the responds of the arch which usually divides the

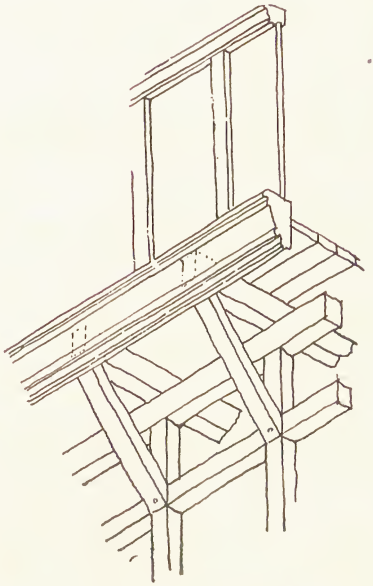


Fig. 14B.—CHANCEL SCREEN

Showing cantilever construction at head of screen, to carry loft.

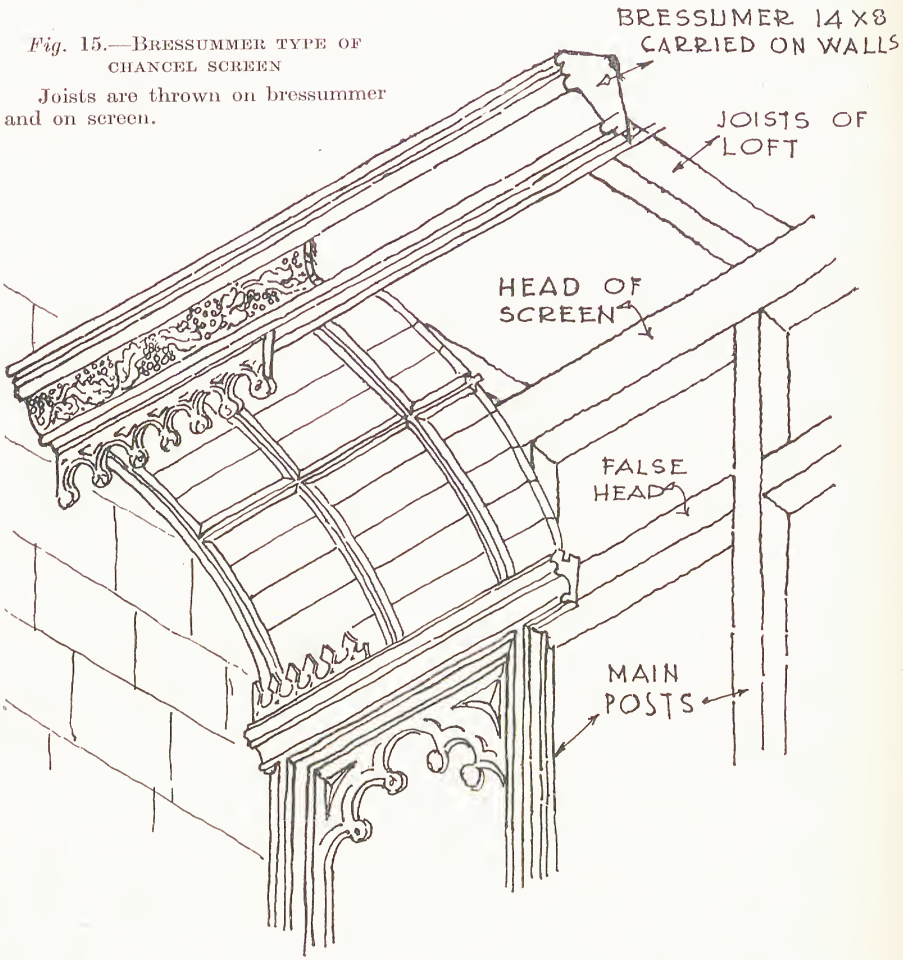


Fig. 15.—BRESSUMMER TYPE OF CHANCEL SCREEN

Joists are thrown on bressummer and on screen.

interior at this spot, and marks the rise of the first step towards the east end.

Simple Type

A simple type of screen comprises a head, two styles, two jambs on either side of the central opening, and cills. The frame is yet further braced by a rail about 4 ft. from the floor. All these timbers are heavy scantlings 6 in. by 4 in. and 6 in. by 6 in., and for the head and cills sometimes heavier. The lower part of the screen is filled in with muntins and solid panels, and the upper is rendered more or less ornamental with moulded mullions and tracery or arched heads. The screen has a pair of gates or doors to close it in the middle, and the centre doorway should be from 4 ft. to 5 ft. wide.

Construction of Screen with Gallery—Rood Loft

Certain screens are surmounted by a gallery termed a rood loft, and the construction of this needs care. Two good methods exist. The one (Fig. 14) is to make the head very massive and to cantilever out joists notched over it at right angles and to support the ends of these by brackets framed into the main uprights. The ends of the joists are tenoned into a trimmer, which in turn holds the wooden balustrade. Solid flooring is laid on the top of the joists, and the braces are masked by panelling either curved out from a false head in the screen, set considerably lower than the main supporting beam, or treated as elaborate wood-panelled vaulting complete with ribs and carved bosses. The disadvantage of this method is that it throws the whole weight of the gallery on to the screen, which must be very solidly built, and may appear too heavy for the church.

Bressummer Type of Screen

The second method (Fig. 15) is to throw a bressummer across the nave some feet in front of the screen, and to lay the joists so that they take a bearing both on this and on the screen. Care must be taken or the bressummer will sag, and it may be supported by braces taken into the uprights of the screen as described for the previous method. The bressummer may be still further supported by a bracket underneath the wall bearing at each end. The construction is hidden behind a deep cove springing from a false head as before mentioned. The mouldings are worked on the solid, and 14 in. by 8 in. is not too large for a bressummer across even a small church.

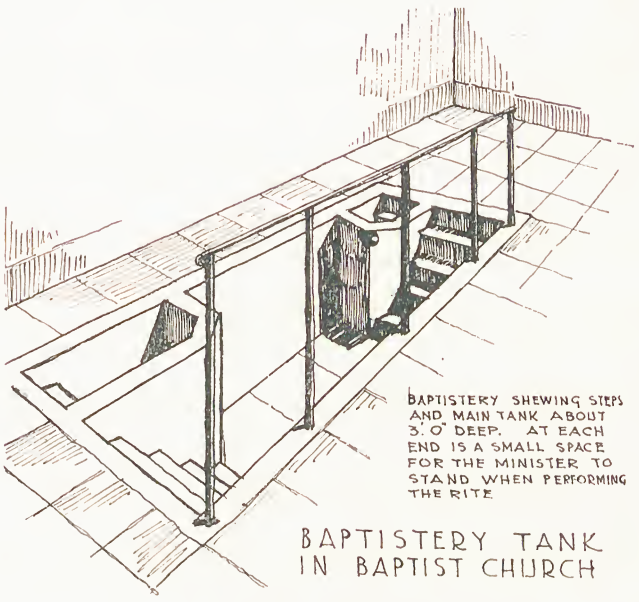


Fig. 16.

FREE CHURCHES

The main difference between the layouts of all Free Churches and those already described is the change of the focal point from the altar to the

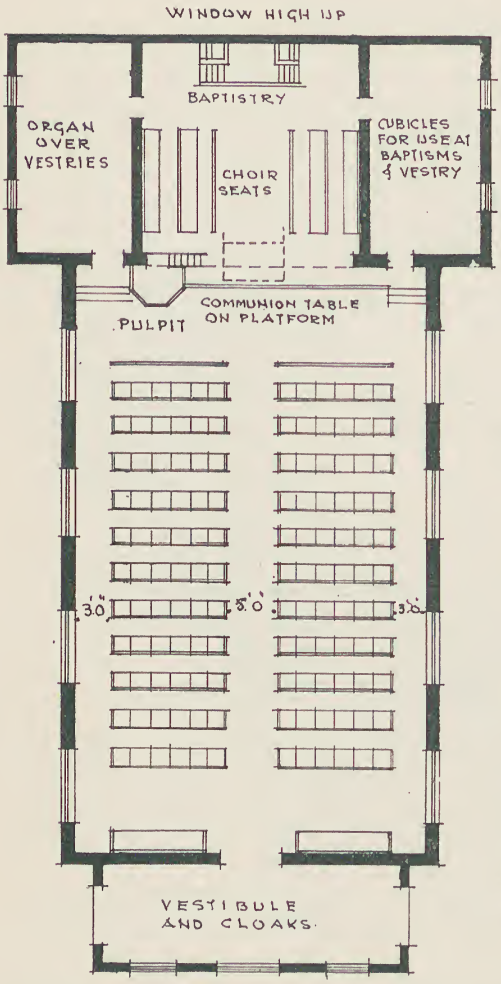


Fig. 17.—PLAN OF A SMALL BAPTIST CHURCH

pulpit. A common arrangement is to have the organ at the east end, with the choir facing the congregation. The pulpit or rostrum is placed in the centre of the platform with usually a stairway up from either side, and below this the platform projects forward into the body of the church sufficiently to accommodate the chairs of the deacons and the Communion table. The seating of the congregation may face directly towards the pulpit, but often the pews in the side aisles are slightly canted inwards to give a better vision.

Baptist

The Baptist churches, however, require a different arrangement on account of the importance of the baptistery. This is a tank of sufficient depth totally to immerse the candidate, and in many modern churches it is placed below the floor level against the east wall, the choir sitting as in an Anglican church, and the pulpit balanced by a reading desk on either side of the entrance to the choir. It is important that a clear view of the baptismal tank be obtained from the body of the church.

The tank itself is about 3 ft. deep and some 15 ft. long, with steps down from either side. Either one or two narrow divisions—about 1 ft. 6 in. wide—also with steps to a lower level but not quite to the bottom of the tank, are walled off for the minister to officiate without entering the water. There should be a clear space in the centre of the tank about 7 ft. long and 3 ft. 6 in. wide, clear of all steps and obstructions.

In quite small churches the baptistery is sometimes near the front of the choir platform, and floored over when not in use.

THE DRAINAGE OF BUILDINGS

PART VI.—THE ONE-PIPE SYSTEM

IN this country the ordinary method of house drainage includes two systems of discharge pipes above the drains. One of these receives the discharges from w.c.s, urinals, and slop sinks above ground level, and the other receives the waste from sinks, baths, and lavatory basins. The pipes receiving the discharges from w.c.s, etc., are called soil pipes, and are connected directly to the drains ; those which receive sink wastes, etc., discharge in the open air into trapped gullies which are in connection with the drains.

In the one-pipe system, sanitary fittings of all kinds, that is to say, w.c.s, sinks, and baths, etc., discharge into a pipe or pipes which are connected directly to the drains without any disconnecting gullies or open-air interception. Until lately this method has not been permitted in England ; but abroad, especially in the colder climates, the principle has long been accepted, partly for the reason that in very cold climates the freezing of water held in gully traps and of waste waters discharged into them would make open-air interception impossible.

Suitability or Unsuitability of System

Before going further, it is very important that the reader should have a clear vision of the possibilities which undoubtedly exist, and which should be taken into account very carefully before coming to any decision as to whether the one-pipe system is, or is not, suitable to any given case. Excellent as the principle of the one-pipe system may be, it does not necessarily follow that its adoption is expedient in all cases. In the first place it has to be assumed that there will be proper maintenance. The fact must be faced that in the vast majority of cases house drains are not inspected, and possibly they will remain untouched during a period of years ; the gullies are neglected, and it is only when blockage occurs that any attention is given, while the traps of basins and sinks are not cleaned until they have become clogged up. It sometimes happens that owing to partial blocking of the interceptor or of the main drain a large quantity of septic matter is held up in the drain pipes, with the consequence that they become very foul without the fact being known, in which case the arrangement of vent-pipes, gullies, and open-air disconnection may prevent the foul drain gas from entering the house. Bad and dangerous as such conditions undoubtedly are, they often exist, and if the one-pipe system had been installed and had been

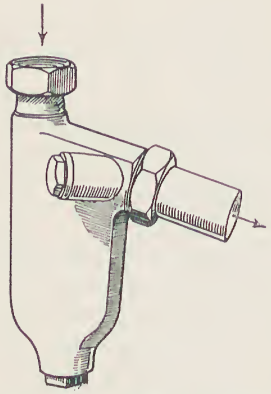


Fig. 1A.—DENT & HELLYER'S DEEP-SEAL TRAP

Note ample provision for disconnection and cleaning.

similarly neglected the danger might have been much greater. Therefore, unless the one-pipe system is to be properly carried out and properly maintained, in the writer's opinion it should not be installed.

If, on the other hand, the work is to be regarded as a piece of sanitary engineering, with proper maintenance, the one-pipe system is safer and is more sanitary than the older method generally in use. For example, in the one-pipe system there is complete avoidance of the emanations of foul air, from waste pipes discharging over gullies round a house and from the gullies themselves, which pollute the atmosphere, generally at places where doors, windows, and ventilation openings occur ; such insanitary conditions may be observed in many enclosed areas in London buildings.

Rules and Regulations

It is necessary to consider first the bearing which rules and regulations relating to house drainage have upon the subject. These must necessarily vary in accordance with the different conditions encountered and, although they may be very useful for local application and may assist the officer of the local sanitary authority in demanding work of a certain standard, they do not do away with the need for careful attention and the application of the teachings of experience and of common sense. The idea that house drains must of necessity be right, because by-laws exist and because the sanitary inspector and the district surveyor have certain powers, is incorrect and misleading, seeing that it is quite impossible for either of these officers to look after all the work going forward in their district in the detail which is necessary in order to ensure good and economical working. The district surveyor has not the spare time to design private schemes, or to make the many inspections required in order to see that such designs are faithfully carried out. Thus an individual responsibility rests upon any person who deals with the drainage of houses, which cannot be transferred to the local authority, and which is not to be avoided by mere compliance with by-laws. It is necessary, therefore, to know when the one-pipe system can be applied, for what cases it is suitable, and whether the local by-laws approve or prohibit its installation.

By-laws which Allow the One-pipe System

With regard to the by-laws, it may be well to ascertain whether any relaxation will be allowed, having regard to the merits of the system as applied to any particular case.

Undoubtedly, the accepted practice in drainage dies very hard. Sanitary engineers have for many years past pressed for an alteration of by-laws to allow a further change of design, and they may be said to have gained their point definitely when the London County Council altered its drainage by-laws in the year 1934 to allow waste fittings of all kinds to discharge into the same pipe if proper safeguards were taken. It is also to be observed that the model by-laws, published by the Ministry of Health for the guidance of local authorities in drafting their own by-laws, after stating that waste pipes from baths, sinks, etc., must be disconnected from the drain by means of a trapped gully, add another clause to the effect that if they discharge into a soil pipe from a water-closet, or waste pipe from a slop sink, they must be provided with suitable traps adequately secured against destruction of the water seal. The model by-laws thereby clearly infer the possible adoption of the one-pipe system. This statement, part of clause number 9 section (C) in the model by-laws, may be of value to anyone who has to discuss the matter with their local sanitary authority. The by-laws of the London County Council are more definite than the model by-laws; under the heading "waste-water fitments," clause 10, the old arrangement is specified in subsection (1), namely, a waste pipe discharging into a gully; and in subsection (2) a specification is given as follows: "(2) If such waste pipe or ventilating pipe is connected directly with any sewage drain, or sewage drain ventilating pipe, or the soil or waste pipe or ventilating pipe of any soil fitment, such waste pipe, ventilating pipe, and any trap connected therewith shall be in conformity with the following requirements:—" This is followed by references to other sections of the by-laws dealing with materials, form of construction and size, trappings of waste pipes, etc. The London County Council has thus published a set of by-laws to enable the one-pipe system to be applied by those who wish to do so.

The Case For and Against the One-pipe System

The basis of the one-pipe system is skill in design, and no one should think of starting a new installation of this type without drawing up full details in the most efficient manner, and preparing the entire scheme. Any description of the details and any application of the method must be preceded by careful study of the reasons for its application, and of the conditions which exist in drainage systems as generally carried out.

It must often have occurred to anyone responsible for drainage work that an apparent inconsistency exists in the fact that, while a w.c. with a simple trap situated inside a house may be connected directly to a soil pipe or to a drain, a trapped sink, which does not differ materially from a trapped w.c., may not be so connected. On the contrary, although

it is trapped in the same manner as a w.c. is trapped, this trap must be connected to a separate waste pipe, which must be made to discharge over a trapped gully in the open air. It might be argued that if the single trap situated inside the house is sufficient safeguard in the case of a w.c., the same protection would be adequate in the case of a sink or bath.

The chief reason why such connections would be dangerous if made from any ordinary sink or bath trap is due to the fact that the traps as they exist are unsuitable, and that the waste pipes are generally arranged in such a manner as to be unsuitable for connection to a soil pipe ; and it is obvious that, if the traps became unsealed, the drains would be ventilated directly into the house. It may be said that there has been complete failure to appreciate the danger which exists in the case of the old arrangement. This danger is greatly aggravated where fittings are connected to a long waste pipe or system of waste pipes. The fact that the interior surfaces of such pipes become exceedingly foul, and that their condition is generally far worse than that of the modern drain, which, when properly cleaned, flushed, and ventilated, is not foul, ought to be recognised more fully. Soap and grease are discharged into the waste pipes and form coatings, and it must be remembered that every form of objectionable matter from washing of materials or of persons also passes into these pipes, and the danger to health where the waste pipes are ventilated into the house becomes apparent. For example, on one occasion within the writer's experience a quantity of blood from a typhoid patient was poured down a basin waste pipe and formed a gelatinous mass above the gully grid below. On another, the sputum from septic throat cases at a school passed into the waste-pipe system. The school had to be closed owing to persistent illness. A number of unsealed traps was discovered in the building, and it was held by medical authority that the bad air drawn into the house through these traps was a fruitful source of trouble. Such cases prove that the ventilation of waste pipes into a building may be very dangerous, even though they have a fresh-air disconnection over a gully. It is clear that if even a trap, on a well-arranged one-pipe system, connected to clean drains, became unsealed, the quality of the air entering the house from the drain would be innocuous in comparison with that described in the case of the older system.

There are many other reasons why a mere connection of existing fittings to a soil pipe or drains would not constitute a one-pipe system ; for instance, soil pipes are frequently made of lead, and where iron pipes are used the joints are generally not of a type to withstand the effect of great changes of temperature, and if baths or sinks were connected to them, without proper consideration of the possibilities, considerable trouble might be experienced. In the one-pipe system this " all-purposes pipe " must clearly be of such a character that it will not be injuriously

affected by the discharge of hot water. A lead pipe under such circumstances might expand and buckle, and with an iron pipe the arrangement and joints must be of such a character that expansion due to heat does not upset them. The ordinary trap on a sink or bath has a $1\frac{1}{2}$-in. water seal, which is insufficient in the one-pipe system.

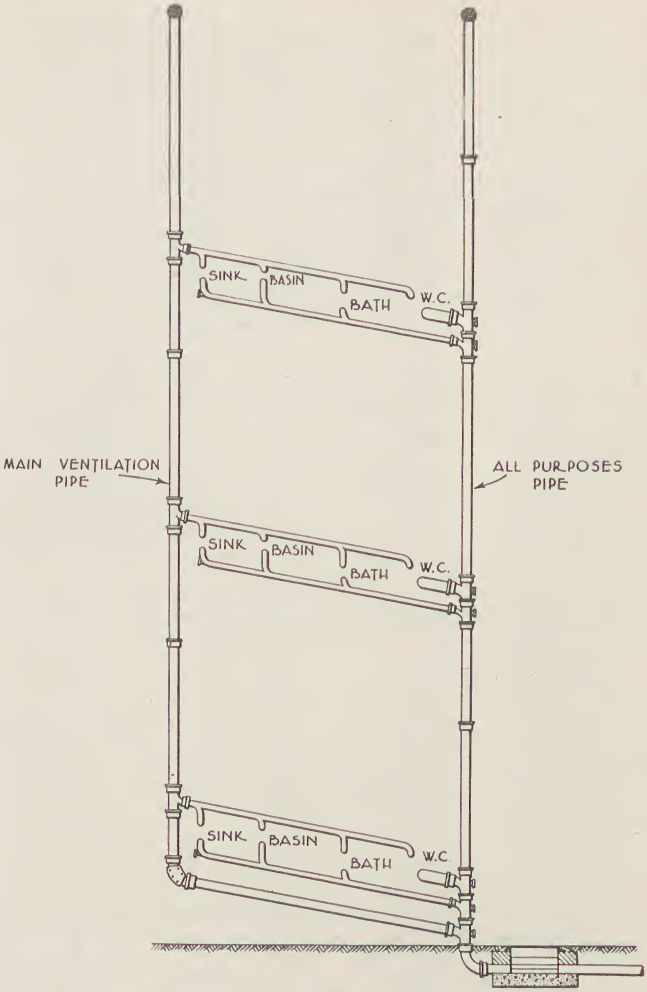


Fig. 1B.—GENERAL ARRANGEMENT OF ONE-PIPE SYSTEM

The One-pipe System

In the one-pipe system all sanitary fittings are connected either directly or through branch pipes to an "all-purposes pipe," which is connected directly to the drain. In order to ensure perfect working, and safety from the danger of unsealed traps, the ventilation must be thorough and complete ; ventilation may be said to be the essential feature of the system. In the museum of the Royal Sanitary Institute a full-scale model exists ; in this model the main waste pipe and the main vent-pipe are of cast iron, the waste pipes are of copper, and the anti-siphonage pipes on the waste pipes, as distinguished from soil pipes, are in each case of the same diameter as the waste pipes ; the traps have a deep seal, such as is shown in Fig. 1A, and ample provision is made for the disconnection and cleaning of all waste pipes and traps, while anti-siphonage pipes can be cleaned at all essential points.

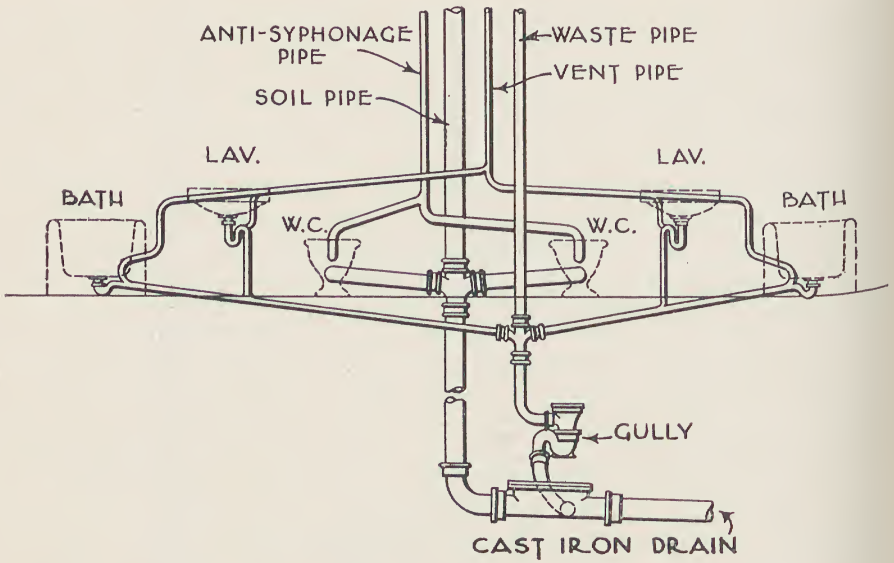


Fig. 2.—EXAMPLE OF SYSTEM AS CARRIED OUT BEFORE THE INTRODUCTION OF THE ONE-PIPE SYSTEM

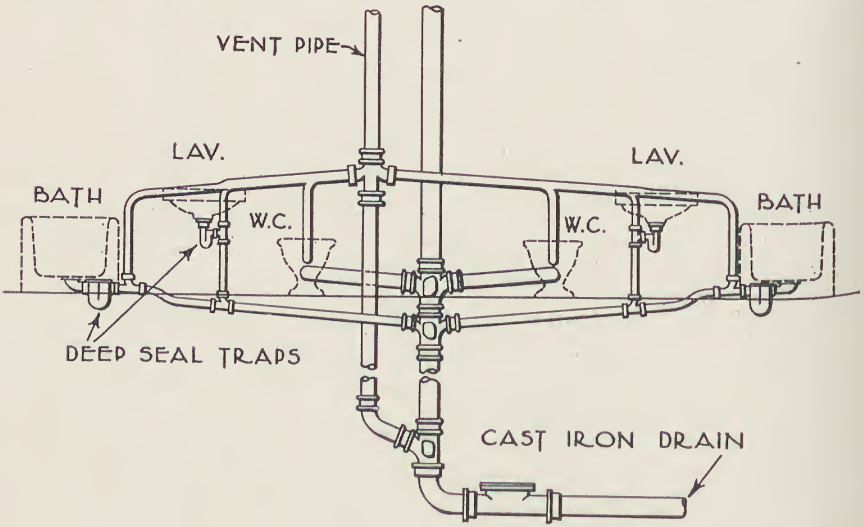


Fig. 3.—THE SAME FITTINGS AS SHOWN IN FIG. 2, ARRANGED ON THE ONE-PIPE SYSTEM

Grouping of Sanitary Apartments

Close co-operation between the architect and the sanitary engineer is essential in order to avoid long and complicated branch pipes leading to the all-purposes pipe ; it is most desirable that sanitary apartments should be grouped as near to one another as is practicable. The soil fittings requiring $3\frac{1}{2}$-in. or 4-in. branches are kept as near to the all-purposes pipe as is possible, and isolated units are arranged so as to discharge as directly as possible into a branch of the underground drainage system rather than to be carried any long distance to the main all-purposes pipe.

Arrangement of the System

It will be seen in Fig. 1B that the soil branches and waste branches are separate. The waste pipes are connected immediately below the point of connection of the soil branches, and the air enters the all-purposes pipe full bore behind the discharge from the higher branches, while compression of the air is rendered impossible by the vent-pipe connection at a lower level and by the anti-siphonage pipe connected beyond the traps of the various fittings in each case. In Fig. 2 the layout for a typical group of sanitary appliances under the older conditions of general practice is shown, and in Fig. 3 the same fittings are shown connected to the one-pipe system. The simplification of the entire scheme due to the elimination of the separate waste stack and its attendant ventilating pipes is made clear. Further, it should be observed that the gully with its connecting drain is done away with. The illustrations (Figs. 2 and 3) are published with the permission of Messrs. Dent & Hellyer Ltd.

It may be necessary under certain circumstances to connect a branch waste pipe into a branch soil pipe ; this arrangement is less satisfactory than that of connecting it into the all-purposes pipe, since soil fittings are only required to have 2-in. anti-siphonage pipes, and the velocity of the air entering a 2-in. pipe must be four times as great as the velocity of the liquid falling through the 4-in. pipe, thus there is a greater pull on the water in the waste-pipe trap than if it were connected to an all-purposes pipe which had a 4-in. vent. If such a connection as that described has to be made, the branch waste pipe should be connected into the top of the semi-horizontal portion of the branch soil pipe, not into the vertical portion, as there will be some air space above the liquid and therefore less likelihood of siphonage.

Preventing Siphonage

As a further protection against siphonage, all ventilation pipes should be as straight as possible and free from bends, and as short as possible. The vertical portions of the branch waste pipes should be short, because the longer the vertical length the more likely is it to cause siphonage, and for this reason it is sometimes best to use 95° junctions rather than

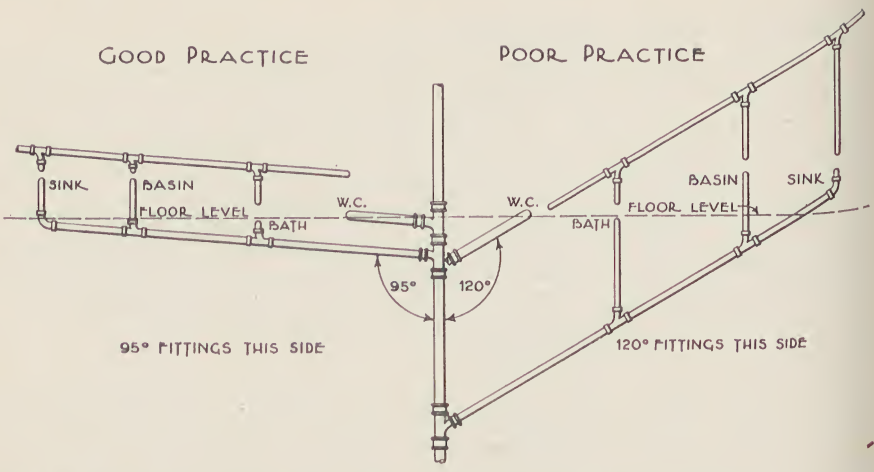


Fig. 4.—PIPE DIAGRAM, SHOWING POSSIBLE ARRANGEMENT FOR TWO SIMILAR GROUPS OF FITTINGS

120° junctions (see Fig. 4), and it is best to place the fittings with low outgoes such as baths nearest the all-purposes pipe (as shown in Fig. 5). These must not be taken as hard and fast rules, but indicate the principles of working.

Ventilation is very important in the one-pipe system, and the small, relatively shallow traps used in ordinary work will not serve, because they would be liable to greater pressures and vacuums owing to discharge of the soil fittings with big flushes, such as do not ordinarily occur in waste pipes. It has been calculated that the flush in a vertical all-purposes pipe descends 16 ft. in 1 second from one floor ; 38·6 ft. in $1\frac{1}{2}$ seconds from three floors ; 64 ft. in 2 seconds from six floors, and 100 ft. in $2\frac{1}{2}$ seconds from ten floors ; these figures are taken from a paper read before the Institution of Sanitary Engineers, written by Mr. W. M. Wild, M.R.San.I. This is purely theoretical, but it is clear that in order to prevent suction the air must enter behind the flush at a similar velocity, and must also be displaced before the flush at a similar rate. Where an interceptor occurs on the drain the need for the relief of pressure is even clearer, an air inlet with a mica flap at the interceptor chamber will not lessen the possibilities of compression ; thus it will be observed in Fig. 6 that very great care is taken to provide against such contingencies. There is first the vent-pipe above the all-purposes pipe which is carried up full bore, then there is the separate vent-shaft, which is connected at the foot of this all-purposes pipe and is carried up to the top of the building. Into this vent-pipe the anti-siphonage pipes from the traps of the various sanitary fittings are also connected. In this manner the formation of any vacuum or partial vacuum, and the

creation of any air pressure in the pipes such as would cause siphonage or unsealing of the traps, is prevented.

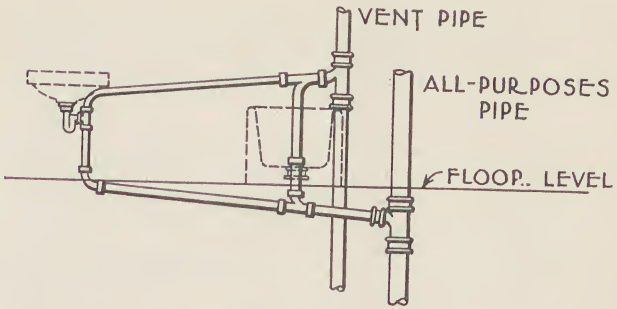


Fig. 5.—DIAGRAM SHOWING BEST PLACING OF FITTINGS IN RELATION TO ALL-PURPOSES PIPE

Avoiding Evaporation of Water Seal

It is also of considerable importance that there should be no possibility of the evaporation of water seals in traps. Experiments have shown that the evaporation of the water seal in a small trap is generally a slow process, such as is not likely to give trouble in ordinary working. On the other hand, there is great danger in any system in which traps occur if the fitting is disused and forgotten. Cases have often occurred where a fitting has fallen into disuse for one reason or another, and where all the water in the trap has evaporated, thereby allowing free ventilation of bad air into the house. Sometimes it has been found that basins have been cased in so as to form a table, and the fact that the basins and traps existed has been forgotten. Such occurrences can only be guarded against by an intelligent system of maintenance, and the danger undoubtedly exists in the one-pipe system as in the older systems.

The Depth of Water Seal in Traps

The ordinarily accepted rule for the depth of water seal in traps in the one-pipe system is that the traps shall be capable of maintaining a water seal of 3 in. where the internal diameter is less than 3 in.; but where the diameter exceeds 3 in., as in the case of w.c. traps, a seal of 2 in. is held to be sufficient.

Connection of Anti-siphonage Pipe

With regard to the ventilation pipe in connection with the trap, viz. the anti-siphonage pipe, this must be connected at a point not less than 3 nor more than 12 in. from the highest part of the trap on that side of the water seal which is nearest to the soil pipe or waste pipe, and it must be fixed in the direction of the flow, as shown in Fig. 7. It should also be noted that, according to the L.C.C. by-laws, where the vertical distance between the invert of the outlet of the lowest trap connected with the all-purposes pipe, and the invert of any horizontal pipe or drain into which the all-purposes pipe discharges, is less than 10 ft., the vent pipe should be continued downwards and connected with

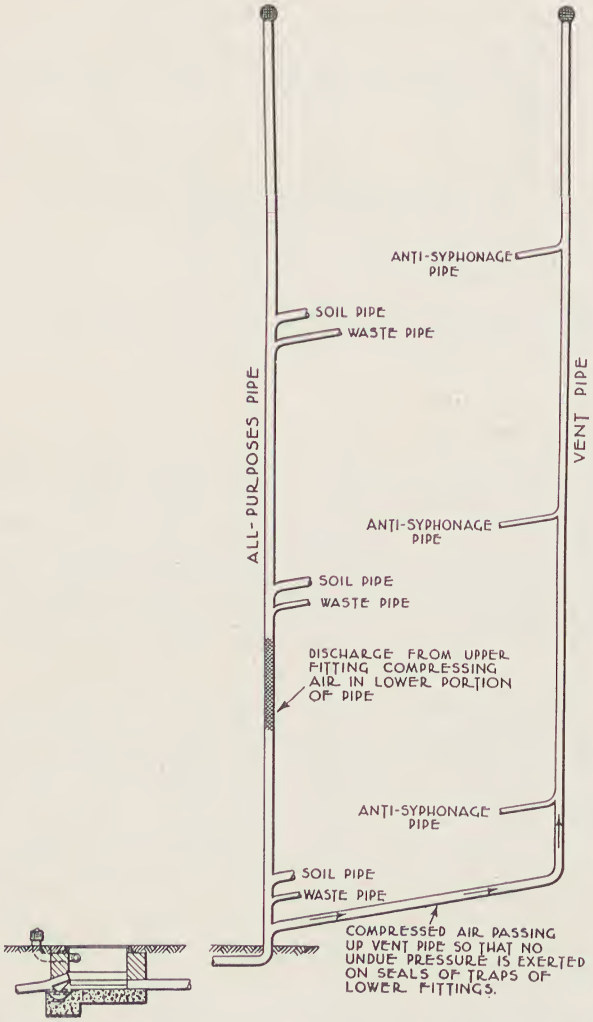


Fig. 6.—DIAGRAM SHOWING METHOD OF PREVENTING BACK PRESSURE OF AIR IN ONE-PIPE SYSTEM

the all-purposes pipe or drain, at a point not less than 9 in. nor more than 2 ft. below the invert of the lowest branch connection, or to a manhole on the drain. It would appear, however, that the ventilation pipe connected to the all-purposes pipe below the lowest connection is always desirable where soil connections occur on the floors above (see Fig. 6 and Figs. 1B and 2).

Sizes of Pipes

It is also a matter of general practice that the branch and main trap ventilating pipes respectively shall have an internal diameter of not less than 2 in. when connected with a soil pipe or waste pipe 3 in. or more in diameter, and that in the case of the branch and main waste pipes, which are less than 3 in. in diameter, the diameter of the vent-pipe shall be two-thirds of the internal diameter, with a minimum internal diameter of $1\frac{1}{4}$ in. It is, however, desirable that there should be no mistake in the matter of ventilation, and for this reason it may be well to make the anti-siphonage pipes of the full diameter of the waste pipes with which they are connected.

It must not be overlooked that the all-purposes pipe carries more than the soil pipe in the ordinary system, and may possibly have to be larger

in consequence. Each case must be considered on its own merits, there is no general rule. The following sizes, which were given in the paper read before the Institution of Sanitary Engineers by Mr. W. M. Wild, may be quoted as a guide :—

APPROXIMATE PIPE SIZES

Soil fittings	3½ in.
Branch soil pipe, two to eight fittings	4 in.
Waste fittings	1¼ in.
Kitchen sink (domestic)	1½ in.
,, ,, (hotels, restaurants)	2 in.
Branch waste (two to eight fittings)	2 in.

ALL-PURPOSES PIPE

Flats, hotels, factories (up to six floors)	4 in.
,, ,, ,, (seven to eleven floors)	5 in.
Domestic dwellings	4 in.
Tenement houses (more than three floors)	5 in.

MAIN VENT-PIPE

(To be not less than half the cross-sectional area of the all-purposes pipe.)

All-purposes	*Main Vent*
3 in.	2 in.
4 in.	3 in.
5 in.	4 in.
6 in.	5 in. (or two 3-in. pipes)
7 in.	5 in.

Rain-water

There remains the important question of rain-water. In some of the installations abroad, rain-water pipes have been connected to the all-purposes pipe with a trap on the branch. This method cannot be regarded as at all satisfactory, seeing that there is every probability of evaporation, resulting in the ventilation of the drains at unsuitable points. Another method is that of connecting the rain-water pipe, running from the eaves gutter or channel, to a pipe which is connected

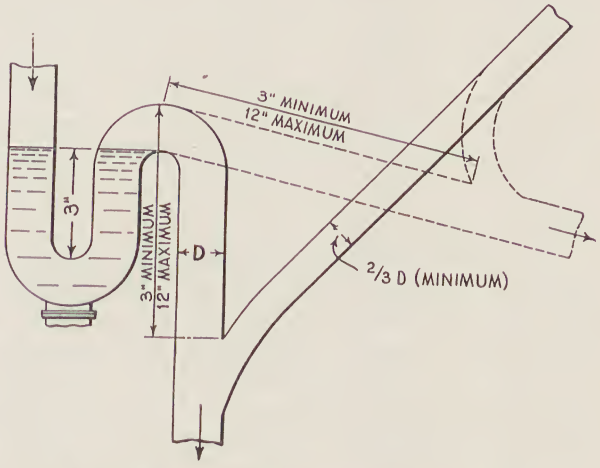


Fig. 7.—CONNECTION OF ANTI-SIPHONAGE PIPE

directly to the all-purposes pipe, and arranging the inlet from the gutter or channel to the branch pipe in such a manner and in such a position that ventilation of the drains at that point shall be unobjectionable. While this method may have its uses under special conditions, it cannot be recommended for general application, for it is obvious that the ventilation of drains near the eaves of the roof, or at any point where there is possibility of the air being drawn into the house, is open to serious objection. The main vent-pipe has to be carried up to a safe point well above the roof, and the ordinary rain-water inlet would be in an unsuitable position. The proper way of dealing with rain-water is to convey it in pipes and drains separately to an interceptor chamber whence it can be carried safely to the sewage drain, and it will be observed that in this case no trapped gullies are required and, moreover, that their existence would be objectionable.

Grease Traps

It is sometimes necessary to consider what steps shall be taken in the case of a large quantity of grease, such as occurs in the washing-up of plates and dishes in a large restaurant kitchen, where the kitchen is situated on the top floor of a high building. In two cases within the experience of the writer, large grease-interceptors existed inside the building on the top floor ; these were found to be very foul, and it is to be observed that unless the grease is removed daily from such traps, and unless the trap is kept scrupulously clean, trouble is likely to occur. In the cases mentioned, the grease traps were removed and the waste pipes were connected directly into down pipes which discharged into gullies, and experience extending over a period of years proved that the quantities of boiling water discharged from the sinks removed the grease, not only from the waste pipes but also from the gullies into which they discharged, and that the short branch drains into which these gullies were connected were also cleansed by the hot flush. Undoubtedly the grease would accumulate in any long system of drains, but provision might be made for its interception and removal at a suitable point outside the building.

General Plan

As already stated, the present tendency is to arrange the sanitary fittings in positions that will facilitate drainage. In modern buildings they are grouped on each floor around a plumbing shaft. This is a vertical shaft running up through the building and open to the external air at the top and also at the bottom. The shaft is generally lined with white glazed bricks, and the soil pipe, waste pipes, vent-pipes or, in the one-pipe system, the all-purposes pipe are fixed in the shaft so that they are open to inspection and so that repairs and cleaning can be carried out safely and without nuisance or interruption.

SANITARY SCIENCE APPLIED TO BUILDING

PART VI.—WATER SUPPLY (*continued*)—PUBLIC SUPPLIES

VARIOUS methods are used by waterworks undertakings for the purification and treatment of water in bulk before distribution, and a brief reference to some of these methods will be of interest. The sources from which waters are obtained are an important factor, as certain waters may require little or no treatment, whilst others will need to be treated in some way or other before distribution. Apparatus is available for the treatment of large or small quantities of water. The removal of harmful microbes is of primary importance, and this may be effected by storage, filtration, and chlorination.

Storage

By storing water in deep reservoirs, a certain amount of purification takes place, as solid particles and a great proportion of bacteria or microbes are precipitated. There are various forms of microbic impurities, of which some are harmless, whilst others are responsible for causing water-borne diseases. Reference has been made to the latter, and the microbes most likely to cause trouble are those which give rise to typhoid fever and cholera.

Sand Filtration

After a period of storage, the water is passed on to filter beds consisting of layers of sand and gravel, of varying grades and thicknesses, laid over a series of collecting channels. The water stands above the top layer of sand to a depth of from 1 to 4 ft., according to the length of time the filter has been in operation, and this depth of water is referred to as the filtering head. Slow downward percolation takes place, solid matter in suspension and most of the microbic impurities still in the water being retained by the filtering medium during the process. The water is collected in the channels and conveyed to the filtered-water outlet.

The filtering process gives rise to the formation of a gelatinous surface film on the top layer of sand ; this film retains microbes, which assist in the purification process. The film is removed at intervals, which vary according to the condition of the water which has been passed through

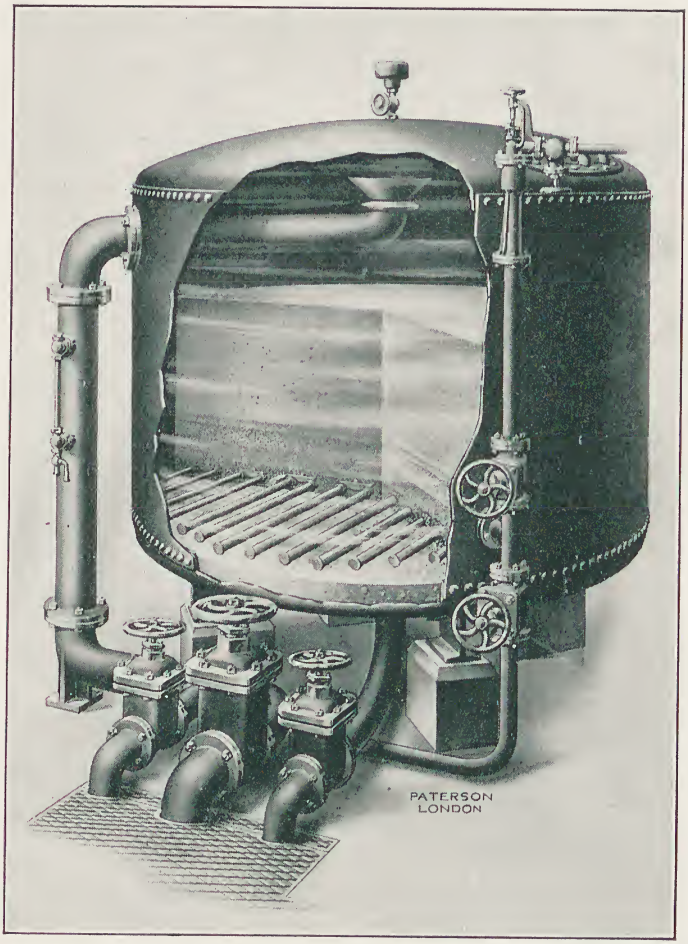


Fig. 1.—THE PATERSON PRESSURE FILTER (AIR CLEANSED)
(*By courtesy of the Paterson Engineering Co. Ltd.*)

the filter. The process is slow in operation, and to overcome this many authorities make use of mechanical filters, which are much quicker in action.

Pressure Filters

These are filters of a mechanical type, and consist of a steel cylinder or cylinders, either vertical or horizontal according to the bulk of water to be treated. Fig. 1 shows a pressure filter of the vertical type; these are made in various sizes up to 9-ft. internal diameter, and comprise a closed cylinder of steel plate with dished ends designed to withstand

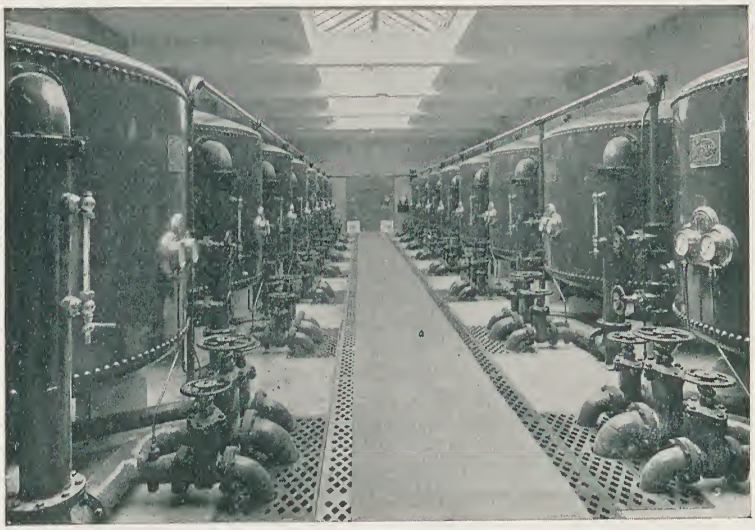


Fig. 2.—PRESSURE FILTERS AT CITY OF BRADFORD WATERWORKS
Capacity: 2,000,000 gal. per day. (*By courtesy of the Paterson Engineering Co. Ltd.*)

the required pressure, the whole being supported on cast-iron feet. Each filter is fitted with inlet, outlet, wash-water, waste-water, by-pass, and air valves of standard sluice pattern. The valves are arranged so as to ensure maximum convenience of operation and control.

Action

The raw water entering the filter is discharged over a diffuser placed above the level of the filtering medium, serving to distribute the incoming water without furrowing the filtering surface, and ensuring the uniform draw-off of the impurities during the cleansing process.

Cleaning

When choked with impurities, the filter bed is cleansed in place by agitation with compressed air, followed by a reverse current of filtered water. The compressed air, obtained from a steam air-injector or by an electrically driven blower or compressor, is applied with equal velocity to all parts of the filter bed ; this ensures a complete and efficient agitation, which loosens the accumulated impurities, enabling them to be readily flushed to the drain by a reverse current of water.

Filtering Medium

This consists of suitably graded quartz sand resting on a series of graded pebble layers, beneath which is situated the manifold-strainer

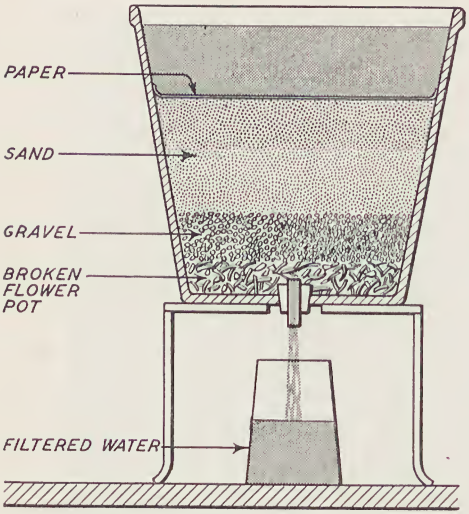


Fig. 3.—HOME-MADE FILTER

system, comprising a cast-iron header with lateral branches covering the entire filter bottom, and provided with numerous equidistant orifices so designed as to ensure not only the uniform draw-off of filtered water during normal working of the unit, but also the efficient and equal distribution of compressed air and wash water during the cleansing process. Fig. 2 shows an installation of pressure filters.

Household Filters

These are of two types, low-pressure and high-pressure, and are used partly for the removal of suspended matter, colour, or odour, and partly for the removal of bacteria, the last named being by far the most important. Every filter should be periodically cleansed, and if necessary the filtering medium renewed. If this is neglected the filter may do more harm than good, and pollution instead of purification of the water may occur. Low-pressure filters usually consist of a vessel containing a layer or layers of sand, charcoal, or polarite, etc.; the water slowly percolates downwards, and is collected in a container beneath. A simple home-made filter, as recommended by Dr. Thresh, is shown in Fig. 3. This filter is easily made by using a large earthenware flower-pot; in the hole in the base insert a cork through which a short length of glass tube is placed. At the bottom, place a shallow layer of small pieces of broken flower-pot; next place a layer of small, clean, washed gravel, and then 6 in. to 12 in. of well-washed, fine, sharp sand. Cover the surface of sand with coarse filter-paper (obtainable from a chemist), and on the paper sprinkle a few pieces of small gravel. The paper intercepts the coarser sediment, and can be easily renewed when necessary. The sand and other material can be removed, well washed, and replaced, or renewed every few months. For water containing much vegetable matter finely granulated polarite mixed with sand in equal proportions may be used instead of the lower half of the layer of sand.

Non-pressure Filters

The Pasteur (Chamberland) non-pressure filter for placing within a cistern consists of a battery of filter tubes connected together and supported in a galvanised, wrought-iron framework. Supplies up to 500 gal.

per day can be provided by this method of filtration. Non-pressure filters of stoneware of the Pasteur and the Berkefeld types are also obtainable for household purposes. These consist of two compartments, an upper part which contains the filtering candle or candles, and a lower part for the reception of the filtered water, which is drawn off through a tap. These filters may be stood on a table or other similar suitable position.

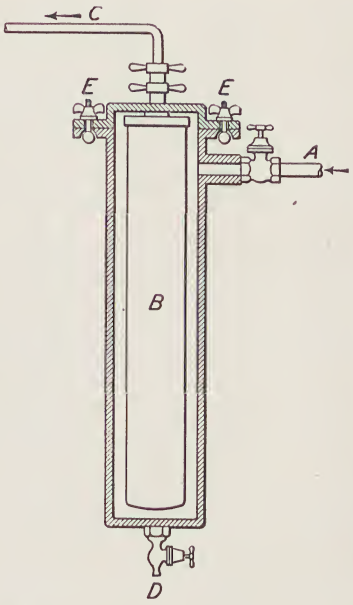


Fig. 4.—BERKEFELD HIGH-PRESSURE FILTER

A, inlet. B, candle. C, outlet. D, wash-out tap. EE, butterfly nuts.

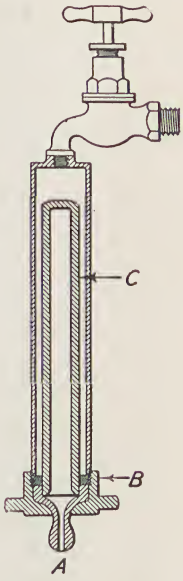


Fig. 5.—PASTEUR HIGH-PRESSURE FILTER

A, outlet. B, cap. C, candle.

High-pressure Filters

For high-pressure filtration the Pasteur and the Berkefeld are two good types to recommend. In each case the water passes through porous candles or cylinders composed of special materials; that in the Pasteur is composed of porcelain, and that in the Berkefeld of compressed Kieselguhr (a special kind of fine earth). Fig. 4 shows a section of the Berkefeld, A being the inlet, B the candle, C the outlet, D a small tap for wash-out purposes; EE are butterfly nuts for securing the top plate (which supports the candle) to the casing of the filter; by loosening these nuts, the candle may be removed for cleansing and sterilisation as and when necessary, which may be daily, bi-weekly, or weekly. For large supplies a filter containing several candles may be obtained. Fig. 5 shows the Pasteur filter; in this type the filter casing screws direct to a tap, and the candle C is removed by unscrewing the cap B. The outlet A of this filter is through B, at the bottom of the casing.

Chlorination

This is a form of treatment for the sterilisation of water in which is ensured the definite removal of microbial growths, including the many types of intestinal bacteria and pathogenic organisms. Pure chlorine is now obtainable in gaseous form, and is a reagent in a state approaching absolute purity; as it contains practically 100 per cent. available chlorine,

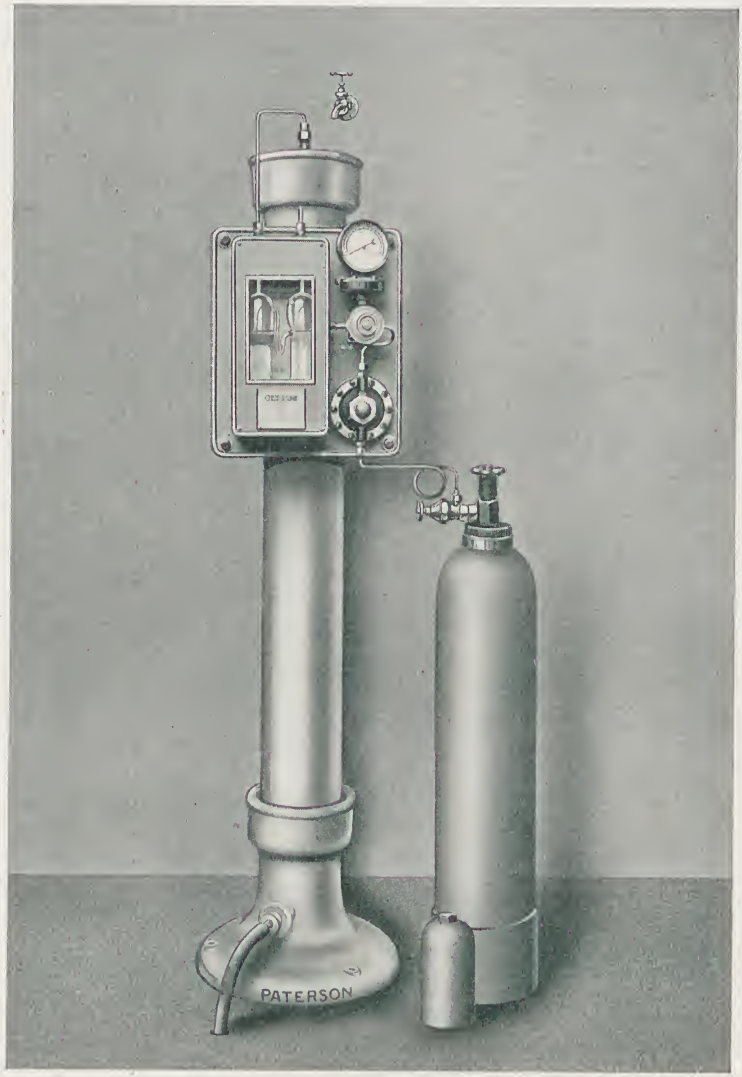


Fig. 6.—PATERSON CHLORONOME (PULSER TYPE)
(*By courtesy of the Paterson Engineering Co. Ltd.*)

its whole weight is available for sterilising purposes. It is supplied compressed to a liquid state in steel cylinders or tank wagons according to requirements.

One of the greatest difficulties to be overcome in the use of chlorine is that whilst dry chlorine gas has no appreciable corrosive tendency, in

the presence of water vapour or moisture it becomes virulently corrosive, attacking the metal parts of the apparatus and reducing it in a very short time to an unserviceable condition. It is therefore of the highest importance that the control mechanism in contact with chlorine shall be constructed of suitable metals, and isolated from dampness or moisture. Fig. 6 shows an apparatus for the introduction of chlorine to water, which has given excellent results. The "Chloronome" comprises essentially the necessary pressure-reducing, flow control, and metering mechanism, mounted on a cast-aluminium panel, also the moisture seal for preventing corrosion of metallic parts, and the means whereby the gas is converted into an aqueous vapour. There are three standard types of Paterson chloronome : (1) the pulser type, capable of sterilising 2,000,000 gal. daily ; (2) the manometer type, which can treat practically any volume of water ; (3) the automatic type, for controlling automatically the rate of chlorine addition in direct ratio to the flow of water through a venturi tube. The pulser type shown in Fig. 6 operates as follows : the reagent is measured volumetrically. The chlorine, from the cylinder, passes through a connector valve, which is coupled to the valve on the cylinder head. The gas is led through a flexible connecting copper tube to a chlorine filter, to arrest any slight deposit which may be carried by the gas from the coil tubes or the cylinder fittings. As the pressure of the gas leaving the cylinder is much too high for accurate measurement and administration, it must be reduced. To ensure a constant low pressure on the regulating valve, two pressure-reducing valves are arranged in series. The gas, varying in pressure from 80 to 120 lb. (dependent upon the temperature of surrounding atmosphere), passes through the first valve, where it is reduced to 20 lb. per square inch, then through the second valve, which maintains a constant pressure of 10 lb. per square inch. The pulsing meter consists of a U-shaped tube with a connection between the two limbs. This U-tube contains a liquid which acts as an inert seal between the dry gas in the instrument and the absorbing water supply, so preventing the ingress of moisture, which might otherwise cause corrosion of the metallic parts. The flow of gas into the inlet limb depresses the column of sealing liquid until it unseals the small vent-pipe, so permitting the passage of the measured quantity of gas from the inlet to the outlet limb. This re-establishes equilibrium, and allows the return of the column of liquid until it again seals the vent-pipe. The cycle of movement is then completed, and another downward stroke commences. The gas is maintained at 10 lb. pressure on the regulating valve, but is measured by the volumetric meter at atmospheric pressure. The rate of pulsation and known volume of the stroke give the weight of chlorine added. By means of the stop valve provided, the attendant can stop and start the apparatus when required without readjusting the regulating valve. Fig. 7 shows chloronomes as fitted for the Metropolitan Water Board.

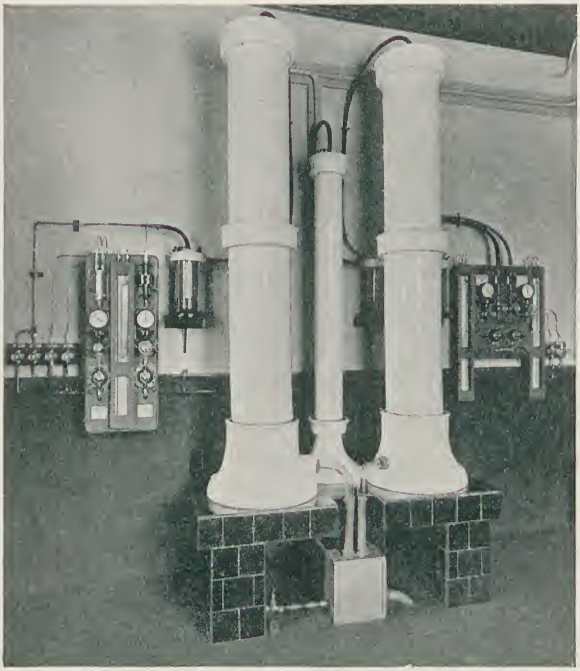


Fig. 7.—PATERSON CHLORONOMES IN USE BY THE LONDON METROPOLITAN WATER BOARD

Duplicate chloronomes—each of 48,000,000 gal. daily capacity. (*By courtesy of the Paterson Engineering Co. Ltd.*)

Distribution

Pipes of various types are now manufactured for the conveyance of water in large quantities through long, unbroken pipe-lines, but the usual method of distribution from the source of supply to the areas to be served is through mains of cast iron or steel. The size of the mains will, of course, depend upon the demand which will be made upon them, and this is a matter for consideration when the scheme for any particular area is designed. Control valves and emptying plugs are provided at suitable points in the mains to permit of repairs or additions being carried out. These fitments are usually arranged so that any section on the branch mains may be shut down without interference with the remaining sections.

Connection to Mains

The method of connection to the mains varies according to the size of the service pipe which is to convey the water into the building. For the small type of building the connection is made by a small brass or gun-metal ferrule having a screw thread, and a union for soldering to lead pipe, or another screw thread for connecting to iron pipe; the main is drilled and tapped to receive the ferrule, the service pipe is then connected and run in a trench across the intervening space to the building at a depth of not less than 2 ft. 6 in. Ferrules may be of the plain type (Fig. 8, A and B), or in the form of a stop valve (Fig. 9). For buildings where a very large supply of water is required, the connection is made by inserting a cast-iron branch in the main, from which is carried a cast-iron or lead service pipe. It is essential that stop valves be placed in

suitable positions to control the supply. Extracts from the by-laws of the Metropolitan Water Board are given here with regard to the items in this particular article :—

By-law 1

(*c*) *Premises.*—"Premises" means any separately occupied house or building or part of a house or building or any tenement or hereditament and the curtilage thereof in respect of which a water rate is payable to the Board.

(*d*) *Service Pipe.*—"Service pipe" means a pipe directly subject to water pressure from the service main of the Board, including the pipe between the service main and the premises to which the water is supplied.

(*e*) *Communication Pipe.*—"Communication pipe" means so much of any service pipe as extends from a service main of the Board to :—

(i) the stop valve fitted on such pipe in a street; or

(ii) where a stop valve is not fitted on such pipe in a street,

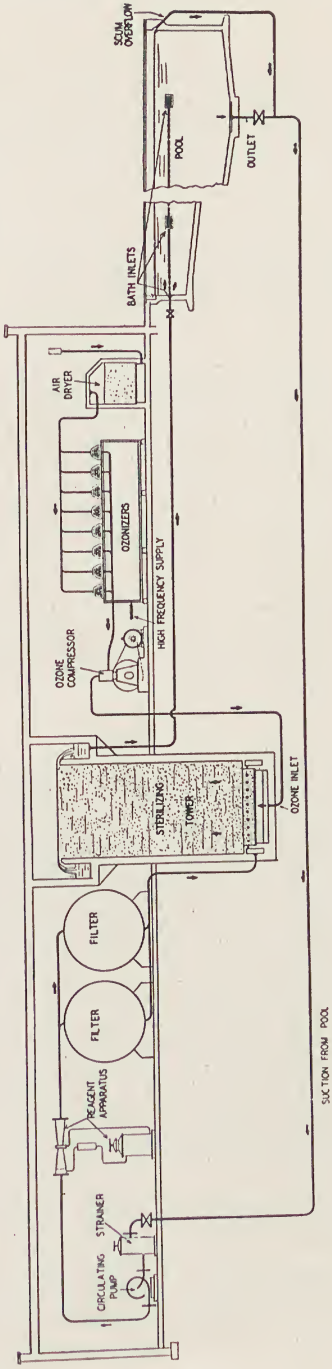


Fig. 7A.—Diagram of filtration and ozone plant for swimming bath or pool

Instead of the use of chlorine or chloramine for the final sterilisation of swimming-bath waters, another form of disinfection is based on the application of ozone to the water. It has the physical effect, also, of aerating the water, and mechanical means of injection of air can be omitted. The ozone is produced by drawing air through a number of ozonisers arranged in batteries. Note that the air used for conversion into ozone is first passed through a desiccator which extracts all the moisture. A compressor or injector draws the ozone from the batteries of ozonisers and discharges it into the base of the sterilising tower through a diffuser, by which it is broken into minute bubbles. The filtered water is reoxygenated and sterilised by contact with ozone in the sterilising tower, the water being delivered into the base of the tower and piped from the top to the shallow end of the bath, where it is introduced at a number of points. Where site conditions are unfavourable to the adoption of the sterilising tower, the diffusion of ozone throughout the water is effected by the use of a venturi-type injector placed in the delivery to the pool. (*By courtesy of the Paterson Engineering Co. Ltd.*)

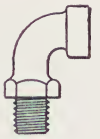


Fig. 8.—PLAIN ELBOW FERRULE SCREWED FOR IRON BARREL

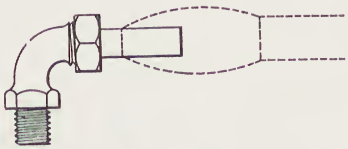


Fig. 8A.—PLAIN ELBOW FERRULE WITH UNION FOR LEAD PIPE

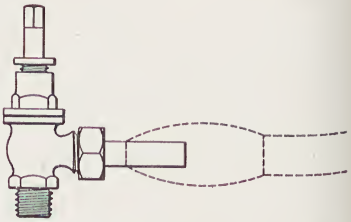


Fig. 9.—SCREWDOWN MAIN FERRULE FOR LEAD PIPE

the point at which such pipe passes the boundary of the street or the point at which such pipe enters any premises in or under the street whichever of these points is the nearer to the service main ; as the case may be.

(*f*) *Supply Pipe.*—" Supply pipe " means so much of any service pipe as is not a communication pipe.

By-law 6

Point of Entrance of Service Pipe.—Every supply pipe shall, so far as is practicable, be so laid as to follow the shortest route between the service main and the consumer's premises.

By-law 7

Communication Pipes Maintainable by a Consumer.—The connection of every communication pipe maintainable by a consumer with any main of the Board shall be made by means of a sound and suitable screw-down ferrule or a cast-iron branch pipe fitted with a sluice valve, and the clear area of waterway shall not be less than that of the communication pipe.

Provided, however, that : (*a*) For lead or ternary-alloy lead communication pipes from $\frac{1}{2}$-in. to 1-in. bore the connection shall be by means of a screw-down ferrule.

(*b*) For lead or ternary-alloy lead communication pipes from $1\frac{1}{4}$-in. to 2-in. bore the connection shall be by means of a union and stop valve attached to a branch pipe to be inserted in the line of the Board's main.

(*c*) For cast-iron communication pipes of 2-in. bore and upwards the connection shall be by means of a branch pipe to be inserted in the line of the Board's main, with a sluice valve fixed as close as practicable to the branch.

By-law 8

Material for Communication Pipes.—Every communication pipe shall be of lead, ternary-alloy lead, or cast iron, and shall have a bore of not less than half an inch.

By-law 23

Underground Pipes.—Every underground pipe, when not beneath a building, shall be laid at a depth to the top of the pipe of not less than 2 ft. 6 in. below the surface of the ground or pavement immediately above such pipe.

By-law 25

Protection from Injury.—Every service or distributing pipe laid or fixed in an exposed situation shall be properly protected from risk or injury.

By-law 26

Protection in Foul Soil.—No service pipe or distributing pipe shall be laid or fixed so as to pass into or through any sewer or drain, or any manhole connected therewith, or into or through any ashpit or manure hole and, except where unavoidable, no service pipe or distributing pipe shall be laid or allowed to remain in contact with any foul soil or any material of such a nature that it would be likely to cause undue deterioration of the pipe. Where the laying of any such pipe through foul soil or injurious material is unavoidable the pipe shall be properly protected from contact with such soil or material either by being carried through an exterior cast-iron tube or by some other suitable means.

By-law 27

Stop Valves on Supply and Branch Supply Pipes.—(*a*) Every supply pipe shall be fitted, near its point of entrance to a premises and within such premises, in a suitable and accessible position, with a stop valve or sluice valve of the screw-down kind, having an area of waterway not less than that of a $\frac{1}{2}$-in. pipe, and not greater than that of the communication pipe. If placed in the ground such stop-valve or sluice valve shall be protected by a proper cover and guard box, or be otherwise adequately protected.

(*b*) Every branch supply pipe supplying water to any separate premises shall have at or near its point of entrance to such premises a screw-down stop valve of a size, and fixed and protected, in accordance with sub-clause (*a*) of this by-law.

(*c*) Every stop valve, sluice valve, extension spindle cover, and guard box fixed on a supply pipe shall be kept readily accessible.

QUESTIONS AND ANSWERS

What is the process of Sand Filtration of Water for Public Supply?

The water is passed on to filter beds consisting of layers of sand and gravel, of varying grades and thicknesses, laid over a series of collecting channels.

Is there a quicker process of Filtration ?

Yes, by the use of mechanical filters.

What is the action of a Mechanical Filter for Water destined for Public Supply ?

The raw water enters the filter under pressure and is discharged over a diffuser placed above the level of the filtering medium, consisting of graded quartz sand resting on a series of graded pebble layers, beneath which is situated a strainer system covering the filter bottom.

What is the purpose of Household Water Filters ?

Removal of suspended matter, colour, or odour, and of bacteria.

What do Low-pressure Household Filters usually consist of ?

A vessel containing a layer or layers of sand, charcoal, polarite, or other medium. The water slowly percolates downwards and is collected in a container beneath.

What is a Filtering Candle ?

A porous cylinder composed of special material—such as porcelain or Kieselguhr. Water is filtered by passing through into the interior of the cylinder.

What is Chlorination ?

The sterilisation of water by the addition of chlorine.

LAGGING FOR PIPES, TANKS, AND CYLINDERS

ANY material which has good heat-insulating properties would serve for "lagging." There are, however, many factors which make most of these materials unsuitable for practical use. To be suitable for domestic hot-water pipes and cylinders a material must have the following characteristics : (*a*) Good heat-insulating properties, (*b*) be easily and quickly applied, (*c*) good surface finish, (*d*) be vermin-proof, and (*e*) not too bulky.

In addition to these requirements it must, of course, be cheap enough to be commercially acceptable.

The types of material commonly adopted for lagging domestic hot-water systems are : (1) Cement compositions, (2) block lagging, (3) hair felt and cardboard.

Cement Compositions

This is probably the most common form of lagging used. Its application, however, is a specialised job if it is to be done without mess and finished neatly. The work is done in two stages and, between the application of the basic covering and the final coat, a few hours' wait is necessary for the basic covering to dry. It is the cheapest material and the most simple form of lagging. For domestic work, particularly, there is now a preference for lagging of the neater proprietary block forms.

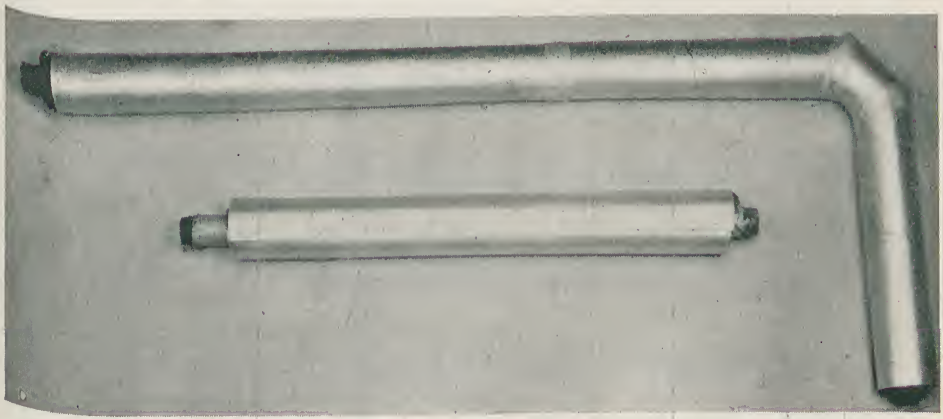


Fig. 1.—Pipes lagged with hair felt and cardboard and finished with aluminium paint

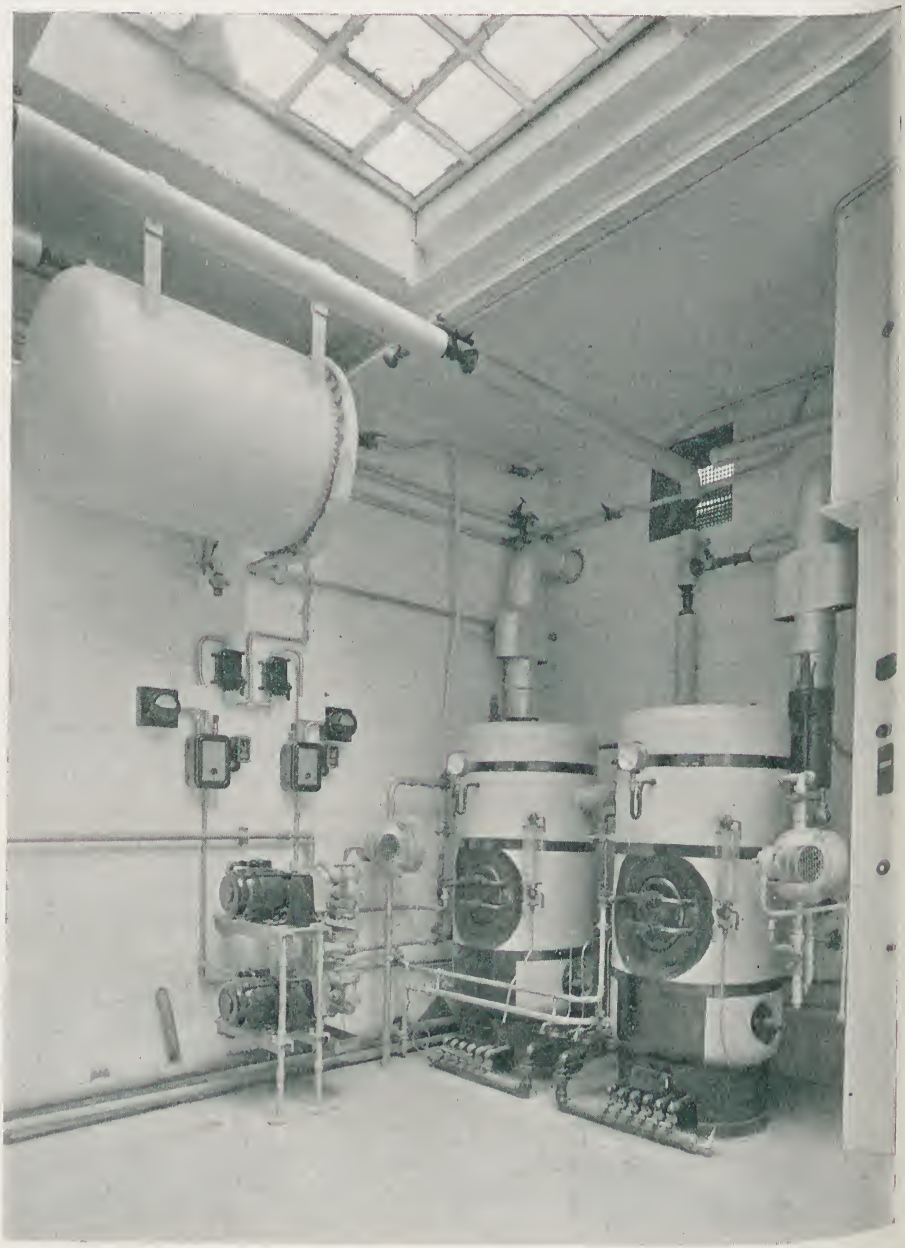


Fig. 2.—A FIRST-CLASS EXAMPLE OF A HOT-WATER SUPPLY SYSTEM LAGGED WITH CEMENT COMPOSITION

The hot-water storage and the adjacent piping can be seen in the top left-hand corner of the illustration.

Block Lagging

Block lagging is merely such materials as asbestos, wool flock, paper, and other similarly good insulators, compressed into cylindrical block form of about 1-in. thickness to suit the various pipe sizes. These cylinders of the lagging are sprung over the hot-water pipes and clipped or strapped in position. For bends and other fittings in pipe runs special forms of the block materials are available. Although the most expensive, the ease of application, cleanliness, and the neat appearance of the finished job are factors accompanying its use which create the preference for this type of lagging.

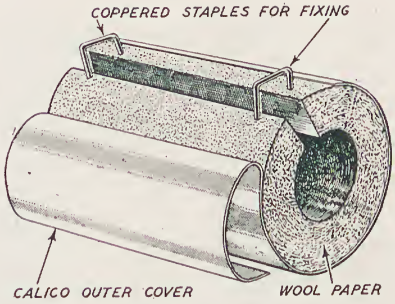


Fig. 3.—ILLUSTRATING ONE FORM OF BLOCK LAGGING

The cylinder of compressed paper is sprung over the hot-water pipe and the join covered by the calico flap which is tacked in position by the coppered staples.

Hair Felt and Cardboard

As a simple, cheap, effective, and universal type of lagging material, hair felt and cardboard can occupy a front place. It is very easy to apply and can be used by a trade workman, without any special experience, to give a neat job. Hair felt of about $\frac{5}{8}$-in. thickness is wrapped around the hot-water pipe and wired in position. Hair felt alone is the most effective form of lagging for a given thickness, but is of very undesirable appearance. To provide a jacket for finishing purposes stout cardboard is wrapped around the hair felt and tacked in position. The joins of the cardboard running parallel with the pipe can be turned to an unseen position, and the butt joins covered with

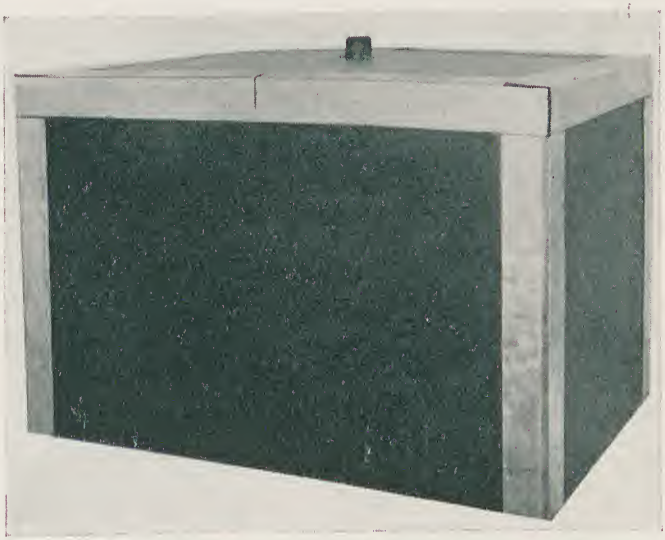


Fig. 4.—A LARGE TANK LAGGED WITH HAIR FELT AND CARDBOARD

Special strips of tin are used to clamp the cardboard in position.

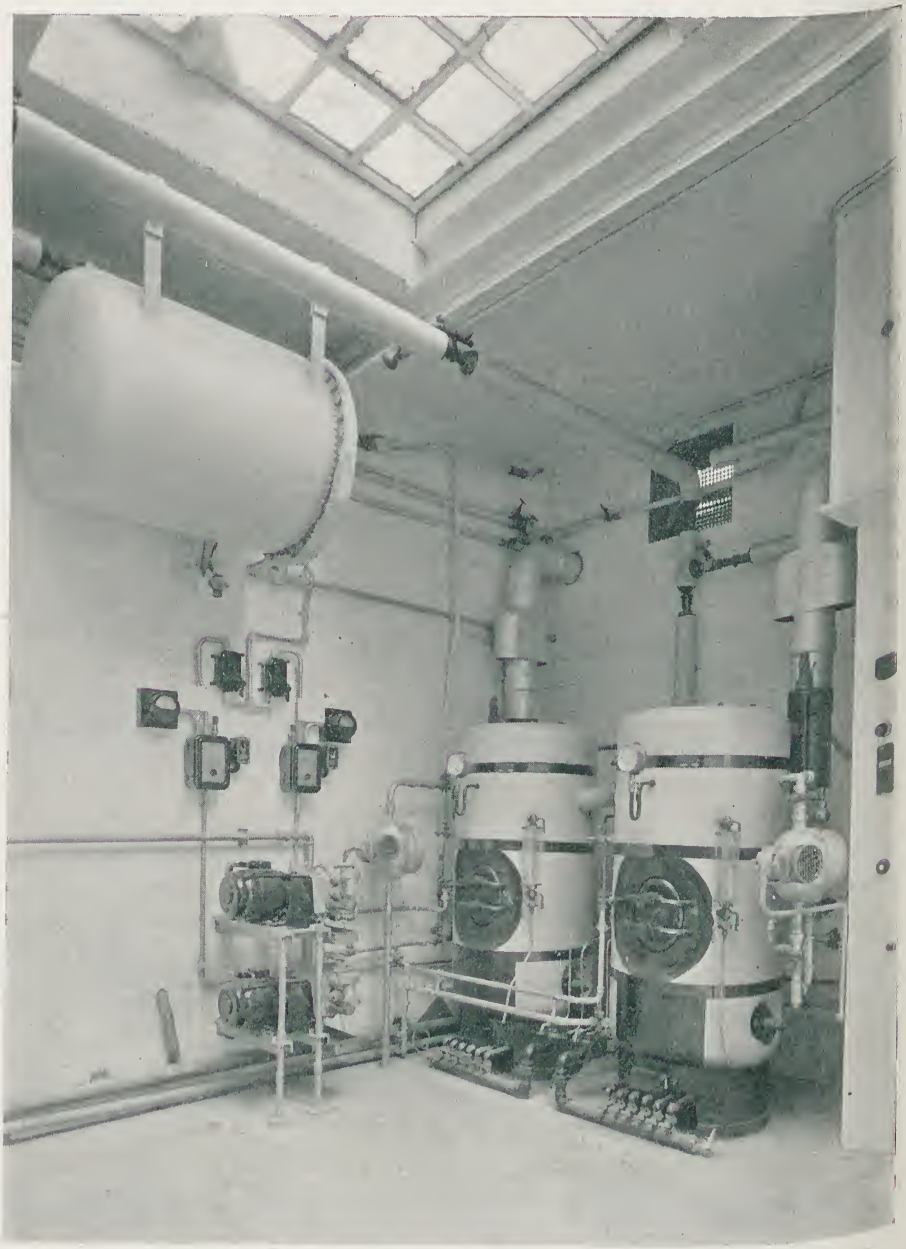


Fig. 2.—A FIRST-CLASS EXAMPLE OF A HOT-WATER SUPPLY SYSTEM LAGGED WITH CEMENT COMPOSITION

The hot-water storage and the adjacent piping can be seen in the top left-hand corner of the illustration.

Block Lagging

Block lagging is merely such materials as asbestos, wool flock, paper, and other similarly good insulators, compressed into cylindrical block form of about 1-in. thickness to suit the various pipe sizes. These cylinders of the lagging are sprung over the hot-water pipes and clipped or strapped in position. For bends and other fittings in pipe runs special forms of the block materials are available. Although the most expensive, the ease of application, cleanliness, and the neat appearance of the finished job are factors accompanying its use which create the preference for this type of lagging.

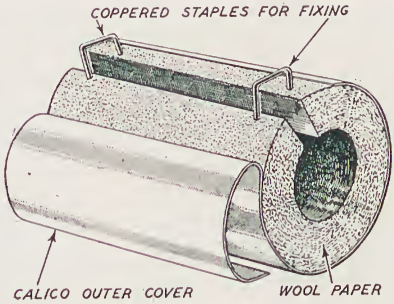


Fig. 3.—ILLUSTRATING ONE FORM OF BLOCK LAGGING

The cylinder of compressed paper is sprung over the hot-water pipe and the join covered by the calico flap which is tacked in position by the coppered staples.

Hair Felt and Cardboard

As a simple, cheap, effective, and universal type of lagging material, hair felt and cardboard can occupy a front place. It is very easy to apply and can be used by a trade workman, without any special experience, to give a neat job. Hair felt of about $\frac{5}{8}$-in. thickness is wrapped around the hot-water pipe and wired in position. Hair felt alone is the most effective form of lagging for a given thickness, but is of very undesirable appearance. To provide a jacket for finishing purposes stout cardboard is wrapped around the hair felt and tacked in position. The joins of the cardboard running parallel with the pipe can be turned to an unseen position, and the butt joins covered with

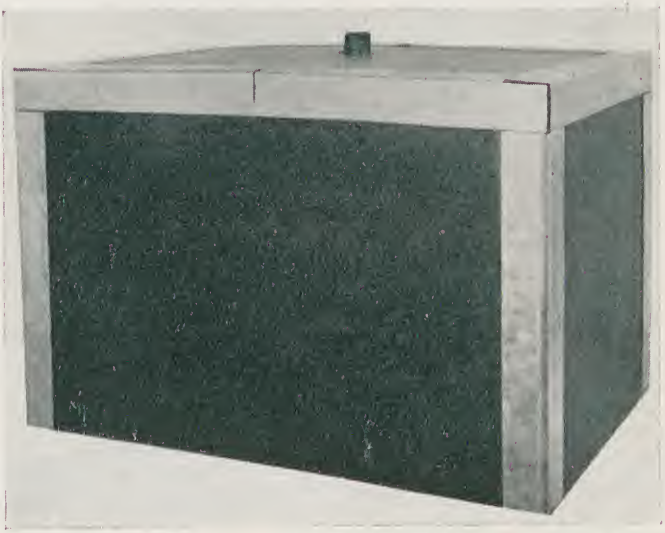


Fig. 4.—A LARGE TANK LAGGED WITH HAIR FELT AND CARDBOARD

Special strips of tin are used to clamp the cardboard in position.

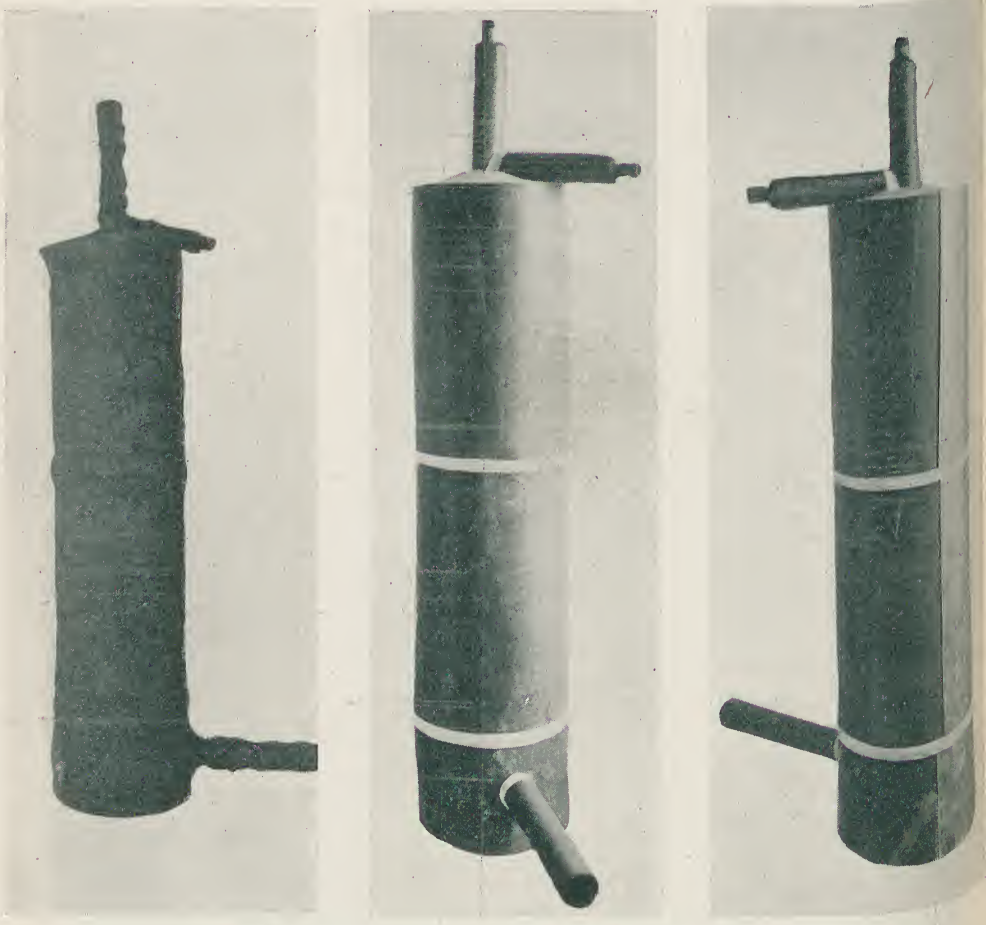


Fig. 5.—AN EXAMPLE OF A CYLINDER LAGGED WITH HAIR FELT AND CARDBOARD

sticky tape. A smooth, neat covering is thus provided which can be painted to suit the surroundings. Tanks and cylinders also can be treated in the same manner.

Aluminium Paint

Where circumstances do not permit the additional expense for covering pipes and cylinders, rather than the system be left in the crude-finished condition, the value of a coat or two of aluminium paint as lagging should not be overlooked. Up to 25 per cent. saving of heat losses can be effected by its use.

ELECTRICAL SERVICES IN MODERN BUILDINGS

MOST architects or building owners would agree that the electrical installation of a modern building forms one of its most important features, and that any serious failure in one of the important aspects of such an installation—lighting, power, or telephones, for example—would cause a more or less complete break-down in the working life of the building's occupants. In spite of this, it is still difficult to persuade the average architect or building owner that reasonable provision should be made for the essential features of the electrical work. Main switchgear is expected to occupy any odd corner not required for other purposes ; rising mains can be tucked away at any point, whether convenient for distribution or maintenance or not ; tubes across floors can take second place to hot-water pipes or plumbing, or be squeezed into a screeding of inadequate depth, whilst partitions are built of materials that cannot be chased, or of thickness too slight to accommodate tubing or switch or plug boxes.

Facilities Required for Electrical Services

In spite of all these difficulties the electrical engineer is expected to provide a complete installation with no visible conduit or fuse boards, that will never fail, and which can be extended or altered without disturbance to decorations or inconvenience to tenants, whilst any suggestion that a margin should be allowed on cable sizes, switchgear, or fuse boards, to meet unforeseen future needs, is turned down on the score of excessive cost.

The impossibility of providing for all contingencies, and of ensuring reasonable continuity of the service under such conditions, is slowly becoming apparent. One occasionally finds an architect willing to provide the necessary facilities, and it is to be hoped that these will be provided more freely in the future than in the past. Such a result can be attained only by a realisation of the difficulties to be overcome, and an explanation of these must be the first step.

The problem is not as a rule serious, except with tubing installations in the modern " fireproof " building, and a brief reference to other systems of wiring and other types of building is all that is necessary. Alternative systems of wiring include cleat work, casing, lead-covered conductors, or tough rubber-sheathed (C.T.S.) conductors.

Cleat Work

Cleat work is suitable only for surface work in factories or similar buildings, and no provision need be made during the building construction.

Casing

Casing is almost obsolete, and must necessarily be surface work on walls and probably on ceilings, so that here again very little or no provision is required during construction.

Lead- or Tough Rubber-sheathed Cable Systems

Lead-sheathed or tough rubber-sheathed cable systems are also largely surface systems, and are not suitable for burying in solid, fireproof floors. They can be and are largely used in domestic work where wood joists and floorboards represent the standard method of floor construction, and here again there is not much need for special consideration in the structural work of the building. Such wires are best threaded through the joists rather than run in notches, and if this is done there is not even need for making any allowance for weakening of the joists due to the notching.

With all these systems the need for adequate switchboard accommodation exists, but such systems are rarely used on the type of installation necessary with a multi-storey building. If used in factories, switchboard space is usually more easily obtained and rising mains can be run on the surface.

Concealed Tubing

The real problem is thus confined mainly to the concealed tubing installation in the fireproof type of building which is now almost universal for present-day office blocks, flats, and stores, and of these the store presents in many ways the simplest problem.

STORES AND SHOPS

In the first place, the probable requirements for the store can be foreseen much more completely in most cases than is possible in office blocks or flats. The building is likely to be in one occupation, and the owner must plan the use of the building in advance in order to arrange for equipment of all kinds. With a reasonably accurate planning of the departments, the electrical services can also be planned in advance, and with definite needs suitable provision for switchgear, cables, and tubing can be arranged more easily than if these needs are speculative. The owner is also likely to employ a maintenance staff, and the engineer in charge will emphasise the need for adequate accommodation, and reinforce the demands of the installation engineer.

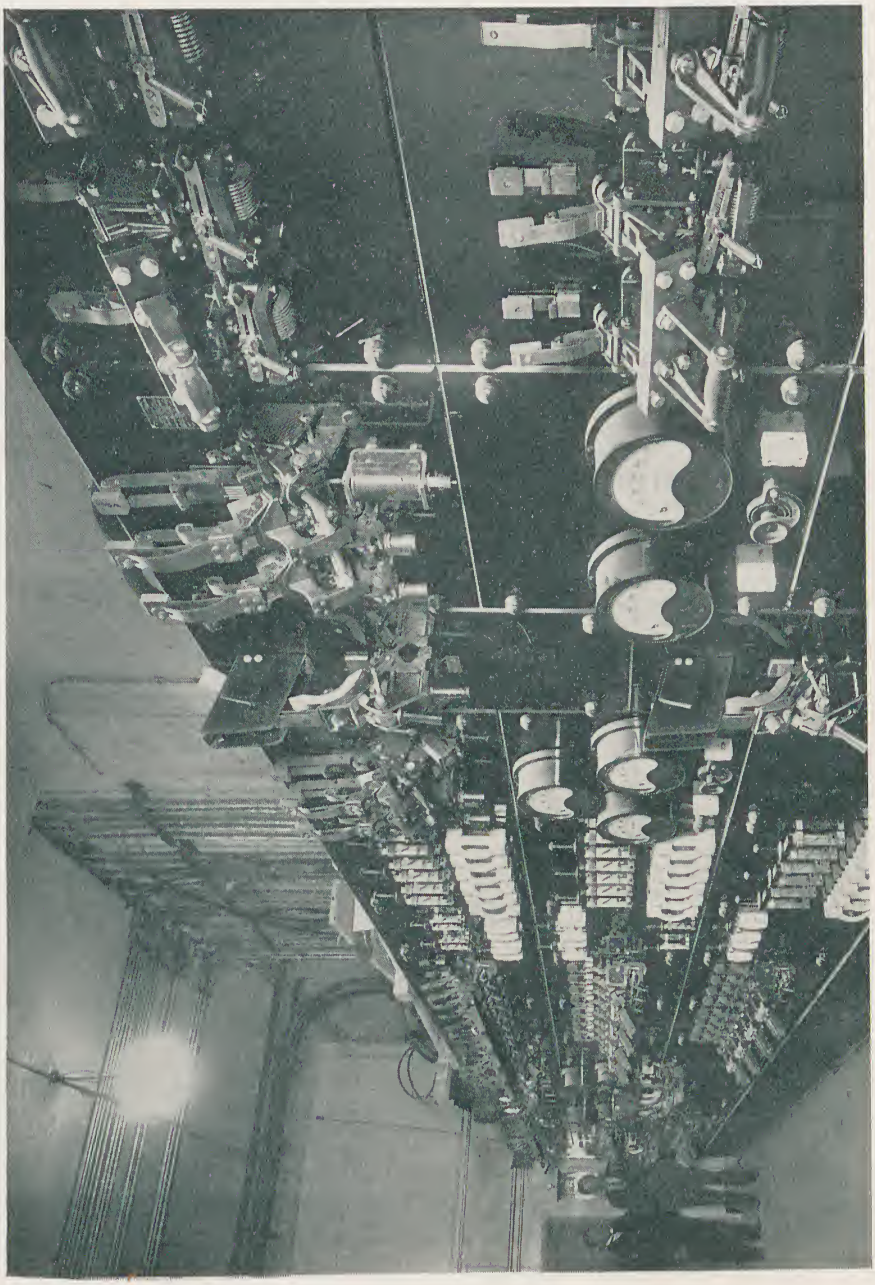


Fig. 1.—MAIN SWITCHBOARD FOR A LARGE STORE

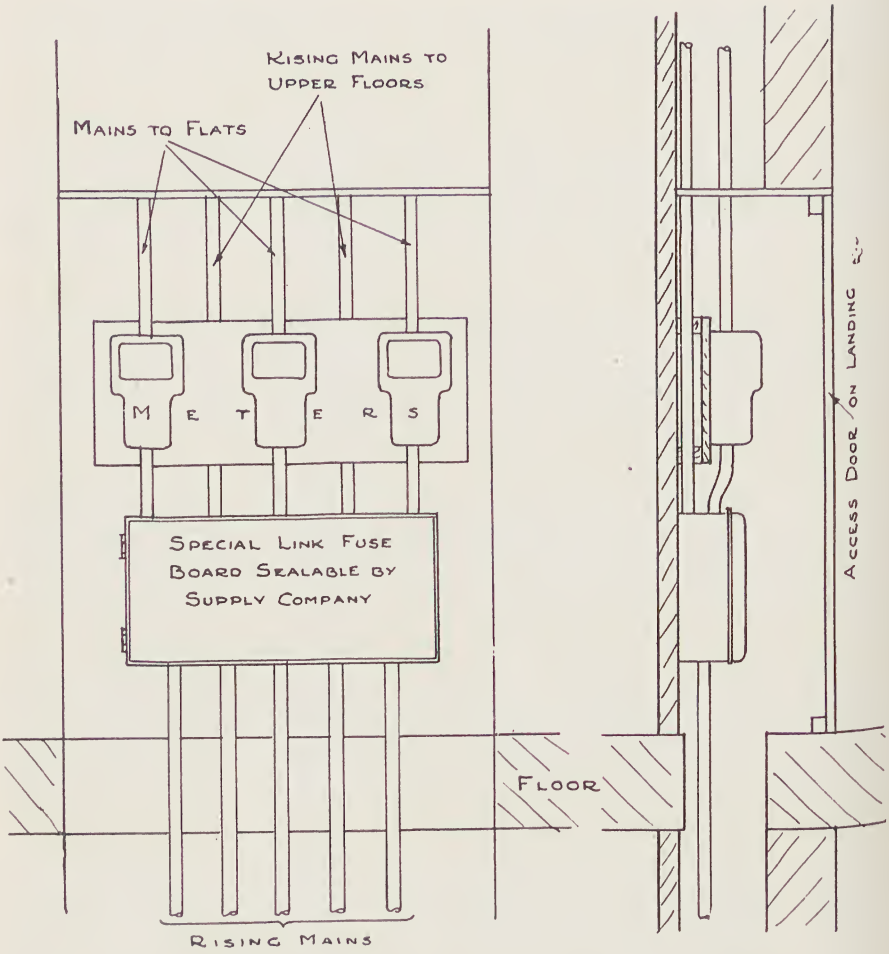


Fig. 2.—CHASE FOR RISING MAINS, WITH ACCESS CUPBOARD FOR FUSE BOARD AND METERS FOR FLATS

A common source of trouble is the need for providing adequate space for the company's service equipment. Where a rising main serves four, six, or eight flats on a floor, some method of separately fusing the service to each flat, which will be under the control of the company, is essential. This means a sealed fuse board, or preferably a meter cupboard, and it is difficult to find a place for this unless arrangements have been made at an early stage of the design. The board must be accessible to the supply company without the necessity of disturbing individual tenants, and there is usually very limited space on landings and staircases. A recess in the rising mains chase can be provided, as shown above, if planned at the right time.

Grouping of Switches

The problem is also simplified in many cases by the fact that the floor areas will not be divided up into a series of separate small units (of varying areas in office buildings), such as is the case with flats or offices, and also due to the absence of separate tenancies, as a result of which alterations can be made without the complications that arise in disturbing one tenant for the convenience of another. The absence of internal partitions, with the consequent grouping of switches at central points, also simplifies the problem.

Floor Tubing for Subsidiary Services

On the other hand, the mere extent of the area in one occupation introduces its own problems, which are also common to a large office building occupied by one firm. The size of the business makes it necessary to provide systems of G.P.O. and internal telephones, staff call systems or other signalling devices, systems of bells, and possibly fire-alarms and other subsidiary services. The tubing for these often involves difficulty if floor screeding is insufficient. Lighting- and heating-tubing will normally radiate from one or two central positions at which the fuse boards are fixed, and will run fanwise out from these in all directions—in other words, these tube runs will not involve much crossing in the centre of the floors. The subsidiary services, on the other hand, may not fit in at all with such a system. Signalling systems and clocks can often be planned so that the equipment fits in with vertical runs, avoiding floor tubing, but this is not possible with telephones and bells, which must be located to suit the requirements of the floors. As a result the tube runs for these services will cross and re-cross those required for lighting and heating, and floor screedings must be thick enough to allow this to be done. Difficulties are sure to arise if these tubing systems must be accommodated in a too-thin screeding.

Make Provision for Possible Extension when Planning

In planning the installation in such buildings, provision must be made for lighting and power beyond the requirements at first thought necessary. Extra show-cases may be fixed at any point, or other special needs arise, and it is well worth while to run a few spare tubes across the floors to convenient positions in the spare corners that almost always exist, such as local storerooms or packing recesses, from which extra points can be extended later. Main switchgear, rising mains, and fuse boards should have a corresponding margin of spare capacity, and a relatively small outlay during the construction stage may easily pay for itself ten times over later on in the avoidance of cutting away and making good and of interference with the work of the staff.

FLATS

The problems that arise in planning an installation for a block of flats, whilst similar in some respects to those for a store, yet have their own special difficulties. In many cases they are due to the fact that such buildings are often erected purely as a speculation, with the object of disposing of the building as soon as it is erected or occupied. In such circumstances the speculative builder regards low initial cost as of paramount importance, and cares little about future maintenance, the difficulties of which may arise only some years after completion, when the early tenants move out and others with different ideas move in.

Difficulties in Providing Adequate Service

In such cases it is very difficult to make adequate provision for a satisfactory electrical installation. Cable sizes must be cut down to the minimum to save cost, and a demand for a few extra or larger fires, or for an electric cooker in a building in which gas cookers were provided, may involve the necessity for an entirely new system of main cables. The probable loads for lighting, heating, and cooking are now much more appreciated than was the case a few years back, but even now many architects and owners cannot or will not realise that the cooking load or a few fires in a flat may require main switchgear and cables many times larger than those needed for lighting. The need for special lighting effects to suit the taste of a tenant may also mean an increase in load of two, three, or four times that required for a normal tenant.

All these facts call for the provision of switchgear, main cables, and services into individual flats of very ample size, and with a margin much above the actual loads, unless the flats are fully equipped with electrical services at the start. Some supply companies have met the difficulty by paying for all or part of the cost of the rising mains, so that future tenants shall not be prevented from obtaining the electrical services they require by the insufficient size of the cables, but this is not general practice, and every endeavour should be made to allow for ample margins on all these basic portions of the work.

Suitable Provision for Companies' Fuses

A further common source of trouble is the need for the provision of adequate space for the companies' service equipment, and for the main switches and fuse boards inside the flats. Where a rising main serves four, six, or eight flats on a floor—which is not an uncommon arrangement—some method of separately fusing the service to each flat, which will be under the control of the company, is essential. This means a sealed fuse board, or preferably a meter cupboard, and it is difficult to find a place for this unless arrangements have been made at an early stage of the design. The board must be accessible to the supply company without the necessity of disturbing individual tenants, and there is

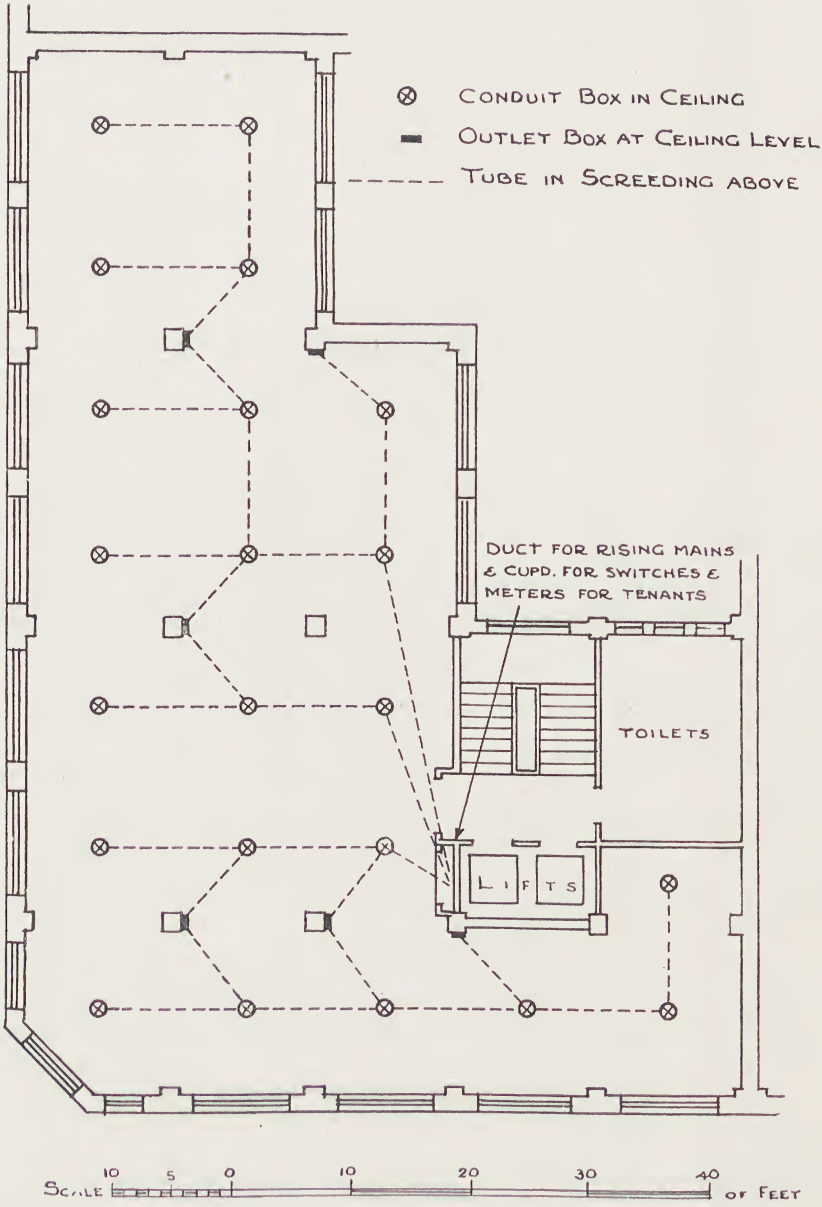


Fig. 3.—SKELETON ARRANGEMENT OF TUBING FOR PENDENT LIGHTING OF OFFICES

Notice the outlet boxes, to which spare tubing is run. These are provided to allow of subsequent surface work to be added without disturbing existing arrangement. Similar systems of tubing can be run in floors, for lighting- or heating-plugs or telephones.

usually very limited space on landings and staircases. A recess in the rising mains chase can be provided if planned at the right time, or a cupboard can be built in, projecting slightly into a flat, with access from the landing.

Switchgear inside Flats

Switchgear inside the flats also requires proper provision from the start. It must often be arranged so that, if necessary, lighting, heating, and cooking loads can be separately metered, as although with one tenant a two-part tariff may be satisfactory, his successor may find separate metering at different rates to be preferable.

This difficulty is being overcome in many cases by the landlord paying the fixed charge and including it in the rent, the tenant paying only the charge-per-unit portion of the two-part tariff, and such an arrangement simplifies many of the electrical problems.

Constructional Problems and Their Solution

Constructional problems continue, however, inside the flats. Every inch or half-inch of screed on the floor reduces the height of the room, and also adds to the cost. Every inch saved in wall thickness increases the area of the rooms and helps to justify a higher rent, and also tends to reduce first cost. There is thus a double temptation, in lower capital cost and increased rental, to cut down floor and wall thicknesses to the minimum, and when this is done trouble is sure to arise with the tenant who prefers brackets instead of the pendants already fixed, or vice versa.

The difficulty is increased by the necessity of making each flat a self-contained unit in which all alterations, maintenance, attention, and so forth can be carried out without disturbing any adjacent tenant—on either side or above or below. The only solution is to provide a very adequate or even excessive allowance of lighting and power outlets, so that one or other of the alternatives available will suit every requirement.

OFFICE BUILDINGS

The position in office buildings is similar to that in stores and flats, according to whether the building is mainly in the occupation of one tenant or let off in separate tenancies which will vary from time to time.

Building with Only One Tenant

In the case where the building is mainly occupied by one tenant the problem is relatively simple, as the important areas will probably be allocated early in the constructional planning, and requirements can be foreseen, but even then the need for ample margins on cables, etc., should be recognised. Re-planning a floor can then be managed without disturbing the whole building to provide new cables from the main switch-

board, but the need for some method of extending telephones, bells, lighting-plugs, and power plugs will always exist.

Building Let Off to Several Tenants

In an office building erected for letting off to tenants the difficulties combine all those for every other kind of building, and probably this is the most troublesome type of building to plan electrically.

Conditions vary widely according to the location of the building. In buildings near the Stock Exchange, a tenant may require scores of telephones for an office area which farther west might require only two or three instruments. In one district the possibility of power or heating for manufacturing purposes on upper floors must be taken into account, whilst in another abnormal lighting for show-cases or special displays may be required unexpectedly.

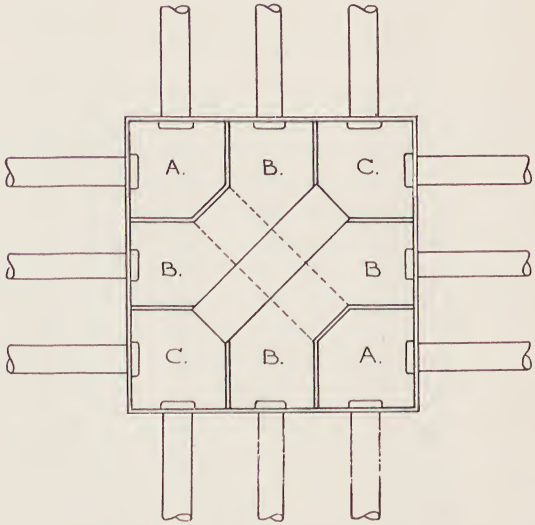


Fig. 4.—FLOOR JUNCTION-BOX FOR TUBE CROSSINGS

Three entirely separate systems of wiring can be run through such a box, without possibility of contact or cross-connection.

The building owner is reluctant to incur the expense of equipment ready for all such possibilities, which may be entirely wasted, but on the other hand, if not provided during construction endless trouble may arise later on. Each tenant will put in his own special scheme, and in the course of a few years the building becomes a maze of services and separate installations which are both unsightly and often dangerous.

The engineer called in to design a scheme that will meet these problems has, it will be seen, many difficulties to overcome, but solutions can be found if reasonable co-operation between himself and the architect can be arranged.

Main Service or Switchboard Room

In the first place, the main service or switchboard room provided must be of adequate size. If the installation is a large one this provision may involve a transformer chamber, in which case the supply authority is to some extent bound by regulations as to the space to be provided. There are no such regulations for the main low-tension board, and only the common sense and good will of the building owner and architect

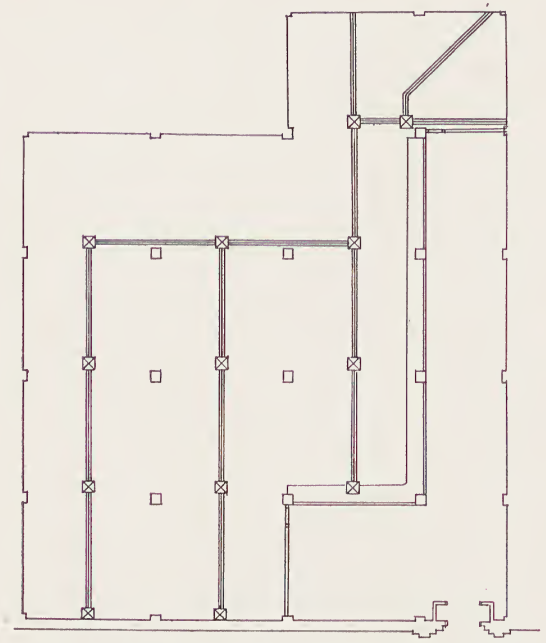


Fig. 5.—LAYOUT OF TUBING IN FLOOR OF GENERAL OFFICE

Three tubes are provided to cross-over boxes, as shown in Fig. 4, and extensions can be made from these as required.

will ensure suitable accommodation, and this will certainly not be forthcoming unless the electrical engineer can emphasise his needs at an early stage in the planning of the building.

Providing Adequate Capacity on Main Distribution System

The second item of importance is the provision of adequate capacity on the main distribution system. If possible, these should be run in suitable ducts, with space for future extensions, and with access on all floors.

In stores, the ducts can also accommodate fuse boards, switches for large areas of lighting, and junction boxes for telephones and other services.

In flats, the company's distribution boxes can be fixed in the ducts, and possibly the meters for the flats, if each duct does not serve too many flats on any floor.

In offices similar arrangements can be made, meters for the large lettable areas being fixed in the ducts or junction boxes, to which the services for smaller areas can be connected, with local meters in each such area.

Ducts

Ducts to serve such purposes must be 6 in. to 8 in. deep, and 12 in. or more in width. Access from floor to ceiling is not essential as a rule, but there must be access doors over any part holding meters and junction boxes, and the rest of the duct should preferably be covered with screwed casings which can be removed in emergency.

If such ducts cannot be arranged some spare tubing should be run up the building with an outlet box on each floor, and this can then be used when the unexpected future demand arises. With careful planning such tubing can be made available for lighting, heating, power, or

telephones, and it can then be used for whatever service is found to be needed.

How to Avoid Future Alterations

The third problem, of avoiding damage on the various floors to suit future needs, is probably the most difficult, and many solutions are adopted to suit varying conditions. The arrangements made must vary with every case, and the following deserve consideration, though it is not possible to say which will be the most suitable without full knowledge of the difficulties and conditions. The problem is much the same in principle whether the building is a store, lettable area in an office block, or large general office area in a building in one occupation. In each case extra service points may be required, whether for lights, heating, small power, telephones, or bells, and the occupant naturally wishes to provide these without the disturbance involved in pulling up floors and moving furniture, carpets, or linoleum, or other floor covering.

Running Spare Tubing—a Simple Ceiling Method

A simple solution is to run spare tubing to as many points as may be thought desirable—usually a compromise between the possible needs and the use of all-surface tubing, based on the cost of the work. Such a scheme for pendent lighting is usually necessary only in buildings of the lettable office type, and a typical arrangement is shown in Fig. 3. With such a scheme the complication of tubing all run on the surface from the fuse boards is avoided, and although surface work will be required beyond the outlets provided, much disturbance can be avoided without unreasonable first cost.

Running Tubing in Floors

A similar system of tubing can be run in the floors for lighting- or heating-plugs or telephones.

To facilitate wiring these floor tubes, whilst avoiding the excessive thickness of screed required if the tube systems need to cross (as is almost certain to be the case), various ingenious types of floor box have been devised, such as that in Fig. 4. Three entirely separate systems of wiring can be run through such a box without any possibility of contact or cross-connections—an essential if it is to be used for lighting or power and telephones, for example. A tray, fixed in the box, covers the wiring channel between sections AA and others, and a second tray carries the wiring from C to C without any contact with those in AA or BB. The depth of such a box can be as little as 2 in., with tubes up to $1\frac{1}{4}$-in. diameter, i.e. much less than would be necessary if two such tubes crossed one another. A trap in the floor to give access to the box is obviously necessary, but this can be arranged so that vertical connections can be made to any one or more of the compartments.

Such boxes can be used to great advantage in an area such as a banking hall, where the desk planning is reasonably definite, giving opportunity to add many extra points of any kind required, the boxes being fixed at convenient spacing to suit the desk plan.

Where Floorboards Are Carried on Filler Joists

Another solution if the floor cover is boarding is to run tubes through channels at right angles to the boards or round the sides of the room, with an adequate number of draw-boxes to which extra tubes can be connected. The lifting of one floorboard at such a junction box will allow further tubing to be carried across the floor, and the worst difficulty —the lifting of many boards to run the tube—is thus avoided.

An alternative to this which may be more convenient is the provision of a removable skirting with the tubes run behind, again with an adequate number of draw-boxes. This is not quite so convenient, as tubes may need to be set down from skirting level to below floor level, but boxes can be used that make this unnecessary, as indicated in Fig. 6.

Such systems are used to their best advantage only where the floorboards are carried on small filler joists $1\frac{1}{2}$ in. to 3 in. above the solid fireproof floor. If this is not the case the solid floor must be chased for every cross-tube from inspection box, wall channel, or skirting, and this involves much disturbance.

Ducts in Floors

With solid floors there is no real solution unless the floor thickness is made sufficient to carry some such system as that designed by the Key Engineering Company, which is typical of several others. With this system a semicircular fibre duct is run across the floors during construction, and before the final screeding is laid, with connections to the tubing system back to the fuse boards, telephone junction boxes, and so on. The location of the ducts is carefully recorded and as many are laid as may be considered necessary. When extra outlets in the floors are required the screed is cut and the fibre duct is bored to give access to the duct, and a special outlet screwed into the duct through which the necessary wires can be drawn out. Separate ducts are required for each class of service.

The great objection to this and similar schemes is the extra thickness of screeding often necessary. Normal screeds are $1\frac{1}{2}$ in. to 2 in. With the Key Engineering Company's ducts the screed might be from $1\frac{3}{4}$ in. to $3\frac{1}{2}$ in. thick, according to the size of the ducts. Such a system may add considerably to the cost of construction, which may be justified in special circumstances.

Ring Main

A scheme that can be used to advantage in buildings in which the lettable office areas are arranged round a central well is to provide

suitable ducts along the corridors, which in such cases are frequently built in during construction. A ring main can be run right round such a corridor, with T-connections into each unit lettable area. These services can be connected inside the areas if several units are let to one tenant, so that only one meter is required, and any re-arrangement of tenancies can be effected without disturbance to the main cables or damage to the decorations. The ring main can be installed to carry both lighting and heating, as these would be separately metered inside the tenants' areas. The disturbance in these areas is not so important, as redecorating is probable in any case with a change of tenancy.

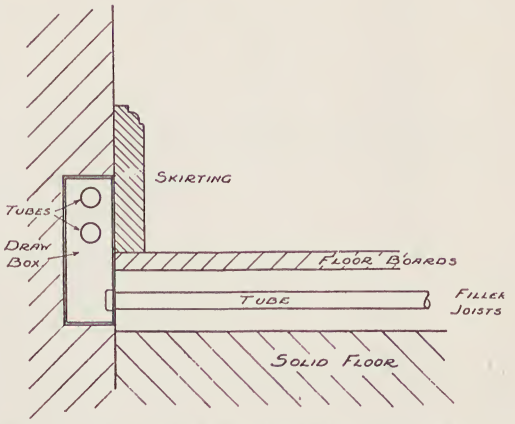


Fig. 6.—ARRANGEMENT OF TUBE BOXES BEHIND SKIRTINGS

The ducts in the corridors must be arranged so that they can be sealed by the supply authority, and the cables protected with sealed fuses where they are connected to the rising mains, but these conditions can be easily met if the details are planned as part of the original construction.

It will be seen that there are many solutions to the difficulties that inevitably arise in dealing with the electrical equipment of buildings of all descriptions. Every building has its own problem, depending on its plan and location, the possible requirements of the occupants, and so on, but a solution can be found for the problem if the building owner and his architect will only realise the need for finding a solution sufficiently early.

SANITARY SCIENCE APPLIED TO BUILDING

PART VII.—WATER SUPPLY *(continued)*—CISTERNS—VALVES—PIPES

RISING MAIN is the term usually applied to the length of service pipe which passes upwards through the building to the storage tank or tanks. The riser should be arranged so as to take the shortest and most direct route, supplies for drinking purposes being taken from it at convenient points.

Storage Cisterns

The usual position for these is at the highest part of the building, so that distributing pipes may be run therefrom to supply the various fitments. Most supplies are now on the " constant " system, and in the case of small property, where there is no hot-water apparatus, it is the practice in some districts to supply all fittings direct from the main. Modern requirements, however, are such that it is necessary to provide storage cisterns in order to hold in reserve a supply of cold water for hot-water and heating appliances, as direct connection from the main to certain apparatus is prohibited.

By providing adequate storage, much inconvenience and annoyance to consumers will be avoided in the event of interruptions in the supply. The Metropolitan Water Board has emphasised that it is desirable to provide taps for drinking and cooking purposes, and to supply all other fittings from a storage cistern ; by doing this the water in the cistern is constantly renewed and thus maintained in the best possible condition against the time when it has to be used for *all* purposes when for any reason their mains must of necessity be temporarily shut down.

Requirements of By-laws

The by-laws of the Metropolitan Water Board state, in regard to capacity of storage, " that every cistern shall be of a capacity of not less than 50 gal., and, if intended to be used as a feed cistern as well as a storage cistern for other purposes, shall be of a capacity of not less than 80 gal."

The Model By-law of the Ministry of Health, No. 21, for the prevention of waste, etc., of water, states " that every storage cistern shall be of a

capacity of not less than 25 gal., and, if intended to be used as a feed cistern as well as a storage cistern for other purposes, shall be of a capacity of not less than 50 gal."

In both the foregoing by-laws, "capacity" means the capacity of the cistern measured from the water line, and "water line" means the top water level at which the cistern is designed to work. The term "feed cistern" means a storage cistern for supplying cold water to a hot-water apparatus.

Amount of Storage

The amount of storage required in the smaller type of house is usually a simple matter to decide, and as a rule is met by the provision of a cistern conforming to the by-laws set out above. For large premises, the amount of storage to be provided will depend upon various factors, such as type of building, number of occupants, number and type of fittings to be supplied, and, in certain cases, provision for fire-extinguishing purposes; for industrial premises, the nature of the work to be carried on is most important, and it is advisable to obtain from the consumers an estimate of the quantity of water likely to be required for various trade processes before deciding on the amount of storage to install. Whether the supply is obtained from a public supply undertaking or from a private source, ample storage should be provided in all cases. When there is a possibility of future extensions of premises it is often an advantage to provide for this in the nature of extra storage.

Position, Covers, and Protection

Storage cisterns should be placed in accessible positions, where they may be readily inspected and cleansed. They should be provided with proper dustproof covers, which must not be airtight, and when the cisterns are situated in exposed positions, they must be properly protected against frost. No storage cistern must be fixed in any position where the water in it is liable to contamination. These are very important items with regard to stored water, and are provided for in the M.W.B. By-laws Nos. 41 and 44, and in the M.O.H. Model By-laws (No. 21), Nos. 32 and 36. The accommodation for storage cisterns varies, but for small buildings the usual place is in the roof space, whilst in the larger type of premises proper cistern rooms are as a rule provided. The type of cover provided in many of the smaller houses often leaves much to be desired, square-edged floorboard being used which soon shrinks, leaving wide gaps for the passage of dust and dirt, especially in those roof spaces which are not boarded on either the under side or top side of the rafters. Grooved and tongued boards are to be preferred for covers. Cisterns in exposed positions should be protected by a metal or wood casing so arranged that a thickness of about 3 in. of non-conducting packing may be placed between the casing and the cistern.

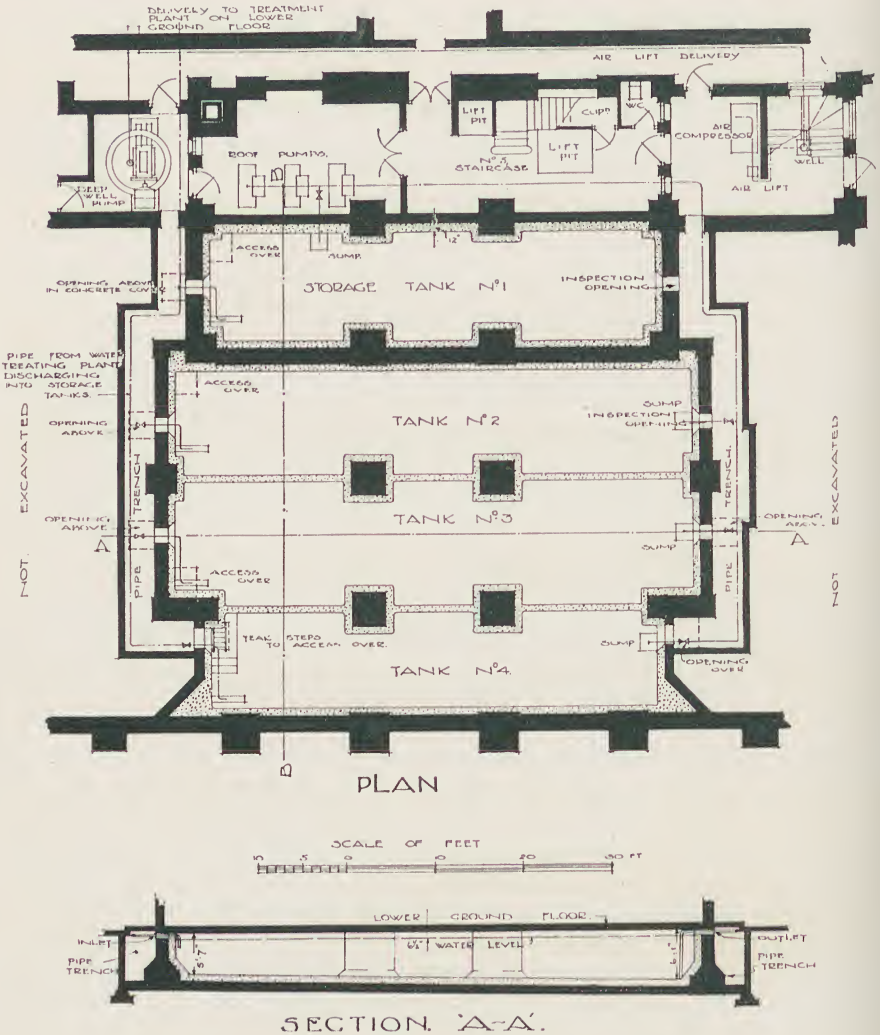


Fig. 1.—WATER STORAGE TANKS IN AN OFFICE BUILDING

City Gate House, Finsbury Square, London. (See page 429, Vol. III, for details of reinforced-concrete casing of the tanks. (*Architects : Sir G. Gilbert Scott and F. R. Gould Wills, F.R.I.B.A.*)

Safes

Though not generally adopted, a safe provided beneath a storage cistern is a useful asset in the event of accident or leakage. One does not expect leakages to occur, but much damage, with its attendant inconvenience, may be caused by a small quantity of water, and this possibility is sufficient to warrant this provision.

Cleaning out Cisterns

An item that is seldom provided, excepting for cisterns in fairly large installations, is a wash-out pipe. The cleansing of cisterns, especially those fixed within the building, is simplified and more effectively carried out when a wash-out pipe is provided. Without it, the wash water must either be baled out or be drained off through the down service pipes (if an outlet or outlets happen to be in the bottom of the cistern); or if they are side outlets, baling and mopping out must be adopted, with the consequent lowering of pails of dirty water through trap-doors, etc.; or possibly by making an improvised siphon with hose pipe to carry the water to a convenient point for discharge. The wash-out pipe can be arranged in various ways, such as an outlet pipe carried to the nearest suitable rain-water pipe, and fitted with a stop-cock with loose key as near to the cistern as possible; or a brass washer and waste with ground-in plug in the bottom of the cistern, or an efficient spindle valve with coupling for iron or lead pipe. Fig. 1A shows a cistern with connections, clean-out pipe, safe, and cover.

Materials for Cisterns

Cold-water storage cisterns may be constructed of various materials, such as stoneware, earthenware, slate, mild steel, cast iron, corrosion-resisting alloy, wood lined with sheet copper or lead. For all ordinary purposes, galvanised mild-steel or wrought-iron cisterns are generally used. These are made up from plates, and galvanised after manufacture. The angle-iron supports that were a feature of all cisterns of this type, for stiffening the top edge, are now dispensed with in many cases, the plates forming the sides being turned over in the form of an inverted channel which acts as a stiffener. Other types are those having welted or welded seams in place of the lap-riveted seams. Screwed outlet and inlet flanges may also be obtained, either riveted or welded on, to suit the requirements of the user. The M.W.B. By-laws stipulate that cisterns of mild-steel plates or sheets shall comply with the British Standards Institution specification for galvanised mild-steel cold-water cisterns, Grade A (By-law No. 40). The Model By-laws of the M.O.H. stipulate that the plates, if of wrought iron or steel, shall be not less than *sixteen* I.S.W.G. before being galvanised or otherwise protected against corrosion, and if the cistern be constructed of wrought iron or steel shall be galvanised or otherwise suitably protected against corrosion after the cistern is constructed (section 31).

For large storage purposes, cisterns of cast iron are used. These cisterns are composed of flanged sectional plates, and are bolted together, rust-cement sometimes being used as a medium for caulking the joints. Outlets are usually formed by machined, faced flanges bolted to the cistern.

Inlet Pipes to Storage Cisterns

To control the incoming water, a fitting termed a ball tap or ball valve must be provided. These valves are made in a variety of patterns, and may be obtained to suit high, medium, or low pressures of water. They must bear distinguishing marks, such as H.P. (high pressure), L.P. (low pressure), or F.W. (full way), cast or stamped upon the body. The respective test pressures against which each type must close are : H.P., 200 lb. per square inch ; L.P., 50 lb. per square inch ; F.W., 10 lb. per square inch. Three well-known types are the "Croydon," "Portsmouth," and "Equilibrium" ; the two last named can be fitted with silence pipes if required, but when such pipes are fitted to a ball valve they must be arranged so that siphonage of the water from the cistern into the service pipe cannot occur when the main is shut down. Siphonage can be prevented by providing for air to be admitted to the body of the valve on the outlet side. The "Croydon" and "Portsmouth" valves can be obtained to suit high or low pressures. The "Equilibrium" is a *full-way* high-pressure valve, and a brief explanation may serve to dispel the doubts which often exist as to whether *full-way high-pressure* valves are obtainable. The valve has a hollow piston or stem, one end of which holds a rubber washer, and the other end a cup leather. The water way at the inlet is full bore, and the barrel which contains the cup leather is of the same bore. As the water enters the valve, part passes through the hollow stem into the barrel, and exerts a backward pressure on the cup leather, and as the inlet and barrel are of the same bore an "equilibrium" of pressure is produced, i.e. the same pressure is tending to close the valve as to open it. There are various other types of ball valves, but space does not permit of detailed descriptions. Fig. 2, A, B, C, shows each type, the ball being shown in only one case.

Fixing Valves

Ball valves must be supported independently of the inlet pipe, unless the inlet pipe itself is rigidly fixed to the cistern. The body of the valve must be in such a position that it cannot become submerged, which means that the valve body must be above the level of the invert of the overflow pipe (Figs. 1A, 3, 4, and 5).

Control of Supplies

Reference has been made to the provision of stop-taps on supply pipes from the main. A new requirement of the M.W.B. is that all distributing pipes from cisterns (usually referred to as down services) must be provided with stop-taps fixed as near to the cistern as possible. This refers to all outlets with the exception of the overflow pipe. It is an excellent provision, and one that hitherto was seldom adopted except in good-class work. The practice of connecting distributing pipes without stop-taps to cisterns is the cause not only of much waste of water by emptying

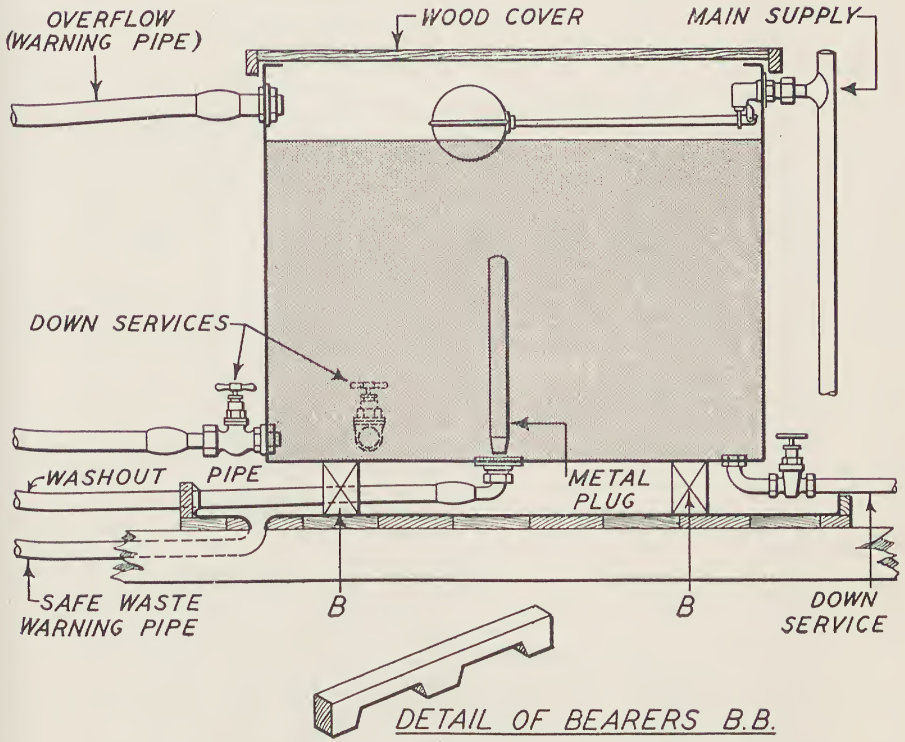


Fig. 1A.—ARRANGEMENT OF STORAGE CISTERN WITH WASH-OUT PIPE

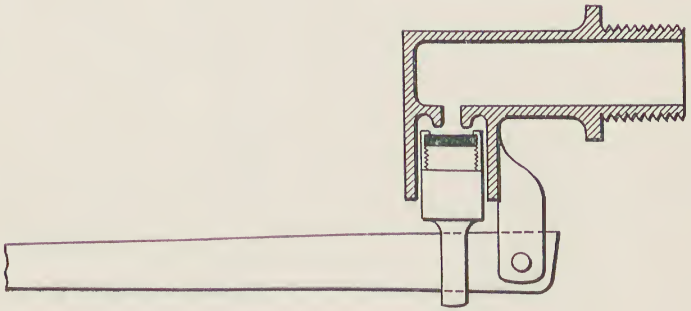


Fig. 2A.—"CROYDON"-TYPE VALVE

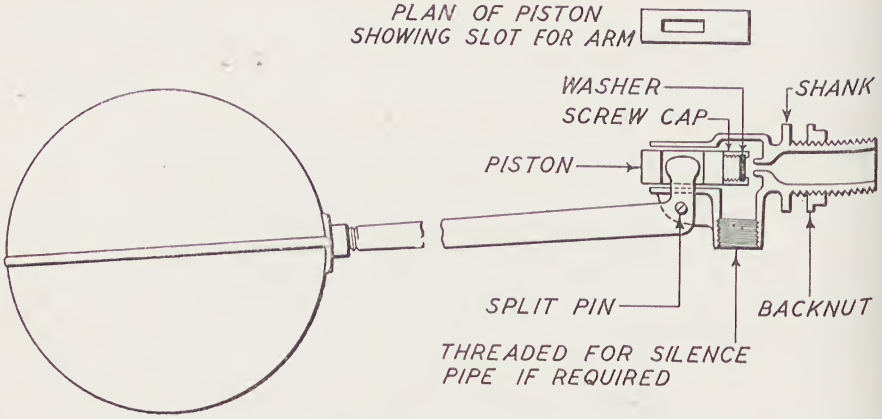
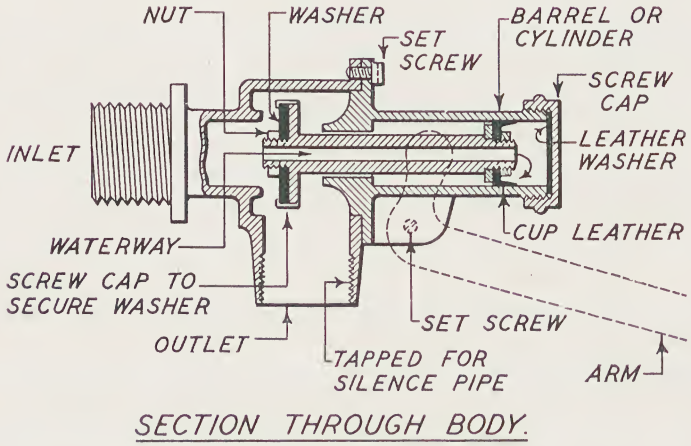


Fig. 2B.—"PORTSMOUTH"-TYPE BALL VALVE



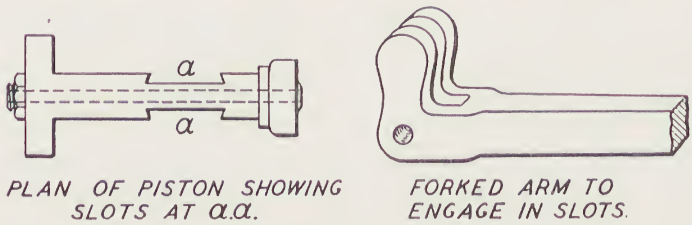


Fig. 2C.—EQUILIBRIUM BALL VALVE

cisterns to carry out repairs to fittings, but of various objectionable methods being adopted when it becomes necessary to "plug" the outlet or outlets in order to carry out repairs. All stop-taps must be of the screw-down pattern, with the exception of gate valves which, providing they comply with the requirements of the by-laws, may be used on distributing pipes, hot-water and heating pipes, and also branch controls to groups of fittings. Stop-valves with cast-iron bodies may also be used. Screw-down stop-taps must be provided with fixed valves, i.e. valves which lift with the spindle when the tap is opened, but yet are free to rotate. The reason for this is to ensure that the water way is opened, as loose valves are liable to remain on the seating, especially when fitted under low pressures. On the inlet side of every stop-valve the word "inlet" or a direction arrow shall be cast or stamped. Fig. 6 is a section through a double-union screw-down stop-valve.

By-law No. 37 (*b*), *M.W.B.* : "The expression screw-down stop-valve shall not include stop-valves of the gate or straight-through type, but such stop-valves, if of brass or gun-metal with spindles of manganese bronze or alloy of equal strength, provided they comply in other respects with these by-laws and are sound, suitable, and efficient, may be used on distributing pipes, hot-water, heating, and circulating pipes, and on branches to control groups of fittings."

Apart from the requirements set out above, the provision of stop-taps to isolated single fittings is good practice, as much trouble and inconvenience may be avoided in the event of repairs being necessary. Fig. 7 is a part-section of a gate valve.

Draw-off Taps

These are mainly of three types, bib, globe, and pillar, and obtainable in a variety of finishes, such as nickel plate, chromium plate, enamelled, or ordinary plain brass or gun-metal. An excellent class of fittings is made of nickel silver ; all types of fittings are obtainable, and they are of 18/22 per cent. nickel silver, are a solid white-metal throughout, and comply with M.O.H. and J.C.S.W.R. specifications. As with stop-cocks, draw taps must be of the screw-down pattern, but certain exceptions are made for taps of special form in the M.W.B. (No. 32) and the M.O.H. Model By-laws (section 25). The former states : "Combination taps, mixing valves for hot and cold water, and all other taps not being of the ordinary screw-down kind, shall be so constructed and of such strength as to be adequate for preventing waste, undue consumption, misuse, or contamination of water, and all such fittings shall be supplied from a storage cistern." The last part of this by-law is important. Mixing valves for baths, shampoo fittings, spring valves, and plug cocks for emptying hot-water systems are examples of special forms. Mixing taps must not be fitted to outlets of water heaters which are supplied direct from the main. Every tap when assembled must resist a pressure of at

least 300 lb. per square inch. Fig. 9 is a section through an ordinary screw-down bib tap.

Flushing Cisterns

The regulations affecting storage cisterns with regard to ball taps and overflow pipes apply also to flushing cisterns operated by hand. An important point to bear in mind is the time taken to fill a flushing cistern. Attention must be paid to the pressure of water available, and a suitable ball valve provided. It is common knowledge that a large number of these cisterns has been fixed under very low pressures and provided with high-pressure valves, resulting in a dribble issuing through the valve orifice. The time limit laid down in the M.W.B. and the L.C.C. by-laws is two minutes, but it is often necessary for these cisterns to fill in much less time than this. The usual permitted flush is 2 gal., but certain provisions are made for hospitals and other institutions, which are supplied with water by measure permitting a 3-gal. flush. Automatic flushing apparatus, such as that used for urinals, drains, trough closets, grease traps, etc., should be fitted with special inlets arranged to measure the water to prevent undue waste, etc. One of the simplest forms of measuring instrument for cisterns designed to work with a " drip " supply is the disc fitting supplied by the M.W.B. It consists of a thin disc of metal, having a tiny perforation through which the water passes. The perforation is made to suit the head of water, so that a given quantity passes in a given time. This fitting is sealed when fixed by the Board's representative. Fig. 8 shows a disc fitting.

Pipes

Pipes are obtainable in a variety of materials which are suitable for the distribution of different classes of water, and the following is a list of various types : steel, wrought iron, cast iron, corrosion-resisting alloys, lead, copper, brass, tin-lined lead, copper-lined lead, the Walker-Health pipe, tin-lined iron, glass-enamel-lined iron, ternary-alloy lead, tellurium lead.

It is, however, essential for the person or persons concerned to become acquainted with the by-laws in force in the district in which it is proposed to carry out the installation of water supplies, and if an installation is to be carried out for distributing a supply from a private source, the nature of the water, i.e. whether hard or soft, etc., must be considered, to ensure a good, wholesome supply. The weights of lead supply pipes are contained in Data Sheet No. 26. For iron and steel pipes the requirements of the British Standard Specifications should be adhered to. Pipes of copper, with screwed joints, should conform to B.S.S. No. 61 (1913), but when compression joints are used the thickness of copper pipes may be three gauges lighter than that given in the foregoing standard specification. For light-gauge copper pipes, B.S.S. No. 659 (1936) should be ad-

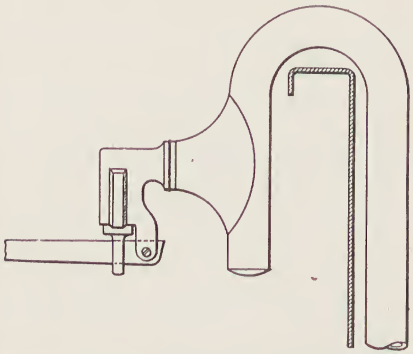


Fig. 3.—WRONG METHOD—SUPPLY BENT OVER EDGE OF CISTERN

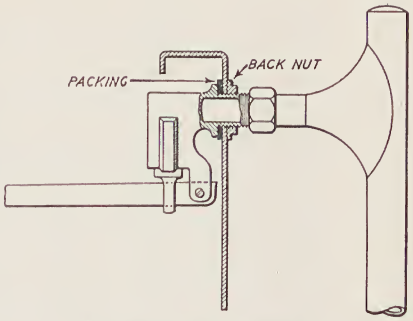


Fig. 4.—CORRECT METHOD

Hole cut in cistern, and ball valve secured with backnut. Supply connected with union soldered to lead pipe.

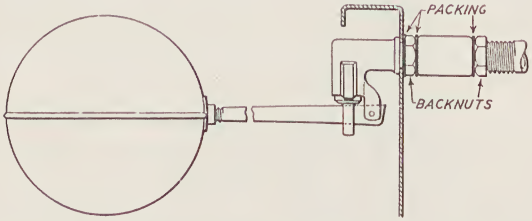


Fig. 5.—IRON SUPPLY-PIPE CONNECTION TO BALL VALVE

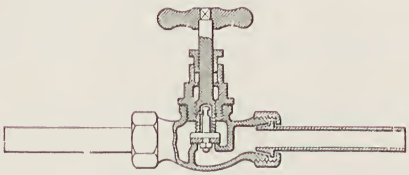


Fig. 6.—SCREW-DOWN STOP-VALVE

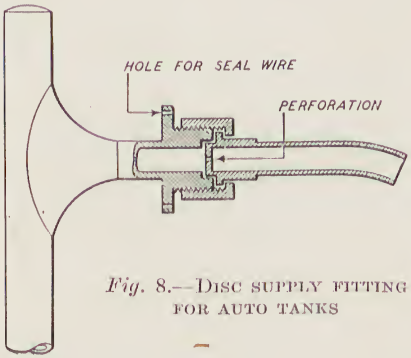


Fig. 8.—DISC SUPPLY FITTING FOR AUTO TANKS

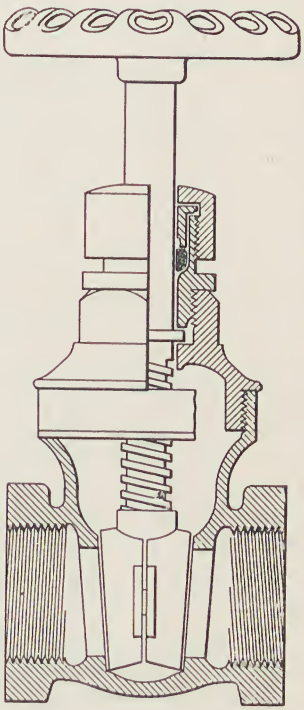


Fig. 7.—GATE VALVE

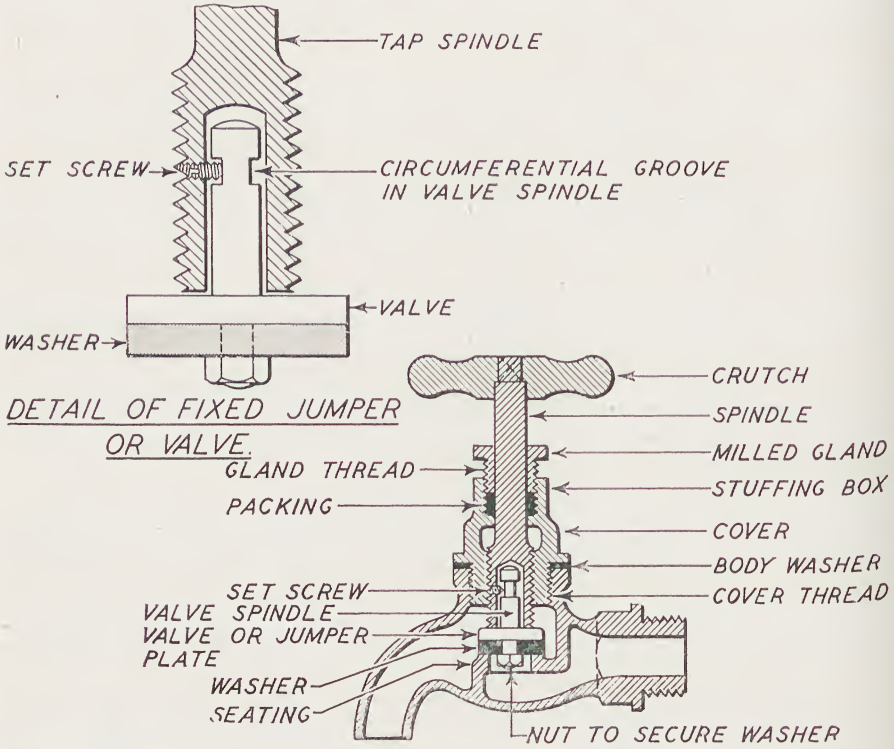


Fig. 9.—SECTION OF SCREW-DOWN BIB TAP

hered to. Bends or curves in any pipe should be made so as materially not to diminish or alter the internal diameter of the pipe in any part. Pipes should be adequately fixed and supported, so as to avoid air locks, and they should also be laid or run so that adequate protection from frost is given. When in exposed positions, and in unprotected roof spaces, they should be properly protected with a suitable insulating material, and pipes should not be laid near to the eaves of a roof. (The M.W.B. specify the distance to be 18 in. from the eaves to the pipe.)

The whole subject is one that requires careful consideration in designing the layout of the water services, and this applies to the cottage equally as much as to the mansion or palatial block of flats. To judge from a few of the smaller installations which have been put in in recent years, it is high time the by-laws were strictly enforced.

Hot-water Supply

This subject is dealt with in another section, but one or two points are of interest in regard to length of single hot-water pipes, and the depletion

of hot-water storage vessels. Much water is wasted when running off the cold or cool water from a long, single pipe before hot water is obtained. To prevent this waste, no tap must be fixed at a distance of more than 25 ft. (M.O.H. amendment) (measured along the pipe to which it is connected) from a hot-water cistern, from a flow pipe, a return pipe, or an expansion pipe. (M.W.B. By-laws Nos. 49 and 49G.)

To prevent a hot-water storage vessel from being emptied, no tap or other means of drawing water must be connected to any part of the hot-water system below the top of the hot-water cylinder or tank in such a way that the level of the water in the cylinder or tank can be lowered by more than one-fourth of its depth. Provided that this prohibition shall not apply to an open tank in which water is electrically heated, or to a tap or other means of drawing off hot water connected to any open tank in which the water is heated. Screwed plugs, and taps with removable keys for emptying hot-water systems for cleaning or repair, are not included in the foregoing. (M.W.B. By-laws Nos. 51 and 51H.)

QUESTIONS AND ANSWERS

What are the Test Pressures against which High-pressure, Low-pressure, and Full-way Ball Valves must close ?

High-pressure, 200 lb. per square inch.
Low-pressure, 50 lb. per square inch.
Full-way, 10 lb. per square inch.

What do the Metropolitan Water Board by-laws require regarding the Capacity of Storage Cisterns ?

Every cistern shall be of a capacity of not less than 50 gal., and, if intended to be used as a feed cistern as well as a storage cistern for other purposes, shall be of a capacity of not less than 80 gal.

What is a Feed Cistern ?

A storage cistern for supplying cold water to a hot-water apparatus.

Are Distributing Pipes from Cisterns required to be provided with Stop-taps under the M.W.B. regulations ?

Yes. The down services must be provided with stop-taps fixed as near to the cistern as possible.

FIRE PROTECTION IN BUILDINGS

EXTINGUISHING APPARATUS

By H. Guy Holt, F.R.I.B.A., M.I.Struct.E.

ENORMOUS losses through fire are sustained annually by the civilised community, and to cope with fire outbreak in this country over 1,500 fire-brigades are maintained. These depend for efficiency on rapidity of action, and the motor engine has done much to improve this : in any case they are dependent chiefly on water supply.

Water is the commonest and most useful extinguisher, as it acts not only by cooling substances to a temperature below that at which combustion can take place, but produces steam, a gas incapable of supporting combustion. Other agents may be employed which can limit or prevent the access of oxygen to the seat of fire.

Alarm Systems

Rapidity of action being essential to the early extinction of fire, a satisfactory alarm system is of the utmost importance, especially where inflammable goods are stored or manufactured. The old-fashioned watchman system had its merits and defects. Automatic alarms are now usually installed in dangerous hazards, and the rules of the Fire Offices Committee are important, and provide, firstly, that each automatic alarm must be connected with a public fire-station, or with an approved central alarm station where direct connection with the fire-station is not allowed.

Usually alarm systems consist of a number of thermostats or detectors, disposed about the building, and connected with an electric-bell system ; in some varieties, a mercury column is used to complete an electric circuit on the temperature rising to a certain point, and in others the metallic thermostat is used, depending on the different coefficients of expansion of various metals at differing temperatures. There is also a further type of alarm, which operates in connection with sprinkler systems, and depends upon the decrease of pressure in the system due to the opening of sprinkler heads.

The Sprinkler System

The sprinkler system is the most effective device up to date for acting as an alarm and an automatic extinguisher at the very first stages of a

fire. Briefly stated, sprinkler systems consist of "heads" spaced at intervals, and connected with water pipes having a standing pressure, so that, on the automatic opening of the "head" by rapid increase of temperature, a stream of water is directed over the fire outbreak.

The Modern Sprinkler Head

The essential working part of the modern sprinkler head, of which there are several types, is the "fusible link." This is in the form of a lever or strut which closes a disc on the end of the water pipe, and consists generally of two or more pieces of metal, soldered together with a composition of bismuth, lead, cadmium, and tin, which are intended to melt at a given temperature, usually about 155° Fahr. The link is held by a bracket screwed on to the pipe, and the bottom of the bracket is so arranged that on the dropping away of the link the water, rushing out of the pipe, impinges on a series of grooves, forming a dome of water which encloses a space of about 10 ft. by 10 ft.

Wet-pipe and Dry-pipe Sprinkler Installations

Sprinkler installations are of two kinds, known as the "wet-pipe" and "dry-pipe" systems. In the former, the whole of the piping and installation is full of water under pressure continuously; this is suitable for temperate climates, but when there is great risk of the water freezing in the pipes is obviously unsuitable, in which case the dry-pipe system is installed: in this the pipes are filled with air under pressure sufficient to hold back the water in the main and supply pipes. On the opening of a sprinkler head the air escapes, and the water then flows into the branch pipes and discharges at the heads.

Sprinkler installations are installed in this country under the rules of the Fire Offices Committee, and substantial rebates on insurance premiums are granted according to the class of installation. This depends on the source of water supply:—

Standard A Sprinkler Installations

Standard A installations require a minimum running pressure at the level of the highest sprinkler of 25 lb. to the square inch, day and night, two independent sources of water supply being provided, both automatic, and always available.

Standard B Installations

Standard B is similar to Standard A, but requires a minimum running pressure of 12 lb. to the square inch only at the level of the highest sprinkler.

"Ordinary" Sprinkler Installations

"Ordinary" installations (which do not come up to standard requirements) must have two separate and adequate sources of supply, one of which must be practically unlimited and automatic.

Sources of Water Supply

There are several variations possible, depending upon the chief accepted sources of supply which comply with the foregoing requirements; they are: (1) town's main; (2) approved elevated private reservoir; (3) automatic pump; (4) approved automatic injector connected with public or approved hydraulic; (5) pressure tanks.

The use of sea water, or water having fibrous and other objectionable matter likely to cause accumulation in the pipes, is not allowed.

Elevated reservoirs or tanks are generally placed in towers to give the required pressure; pressure tanks are used in positions where the elevated tank is not permissible. Pressure tanks are placed as high as possible in connection with the installation, as it is found in practice difficult to maintain a constant air pressure at over 100 lb. per square inch.

Design of Sprinkler Installation

The design of the installation depends upon the foregoing points regarding the sources of supply to be adopted, and then upon the spacing out of the requisite number of sprinkler heads and laying down the pipe lines and sizes.

In factory buildings, one sprinkler head to every 100 sq. ft. of floor area is the general spacing adopted, but varies slightly; concealed roof spaces must be sprinklered, and goods must not be stored or piled in such a manner as to cause obstruction of water flow from the heads.

Drenchers

Drenchers, referred to in connection with external hazards, page 400, Vol. II, consist of a number of heads fixed over the tops of windows and other external openings, and over roofs exposed to external hazards. The pipes are empty, but the water supply under pressure is turned on by a hand-operated valve. A spread or curtain of water is thus played over the area to be protected. Water supply must be distinct from that of the sprinkler installation.

Hydrants

Hydrants are installed in a variety of ways, depending on circumstances. The water supply is by pumps delivering water to underground mains and branches leading to the valves, which may be external and internal; a line of hose, with nozzle and coupling ready for connection

to the valve, is kept nearby. Underground hydrants are generally either ball-valve or screw-valve type, with bayonet or threaded connections ; they must be frost-proof. The rules of the Fire Offices Committee should be complied with to obtain the best insurance results.

Bucket System

Simple first-aids in extinction include bucket systems, the chief requisites being that the buckets are inspected daily to ensure that they are kept properly filled with water, and not used for any other purpose. Buckets with lids to prevent rapid evaporation are supplied ; buckets filled with sand should be kept to deal with electric or oil outbreaks.

Chemical Extinguishers

Chemical extinguishers are of various types, practically all of them depending on the projection of water saturated with CO_2 upon the burning mass ; they generally consist of a metal cylinder or cone containing sodium bicarbonate, from which the carbon dioxide is freed by the action of an acid contained in a bottle or glass tube which is broken or inverted in action to allow of the escape of the acid. The pressure of the gas generated is sufficient to propel the water, which fills the metal vessel, for a considerable distance.

Modern extinguishers are tested to several times the pressure to which they will be subjected in action before leaving the manufacturer's works ; several fatal accidents occurred years ago, on account of the bursting of extinguishers of the type then used. A hydrostatic test of about 15 atmospheres, according to the size of cylinder, is now considered absolutely necessary.

Extinguishers for Electrical and Petrol Fires

In addition to the foregoing types, there are also " powder " extinguishers, to be used chiefly in electrical and spirit fires, and the " foam " type, which is extremely useful in petrol and oil fires, and acts by casting a thick foam over the blazing surface and cuts off the burning vapour from the petrol, thus excluding the air ; the foam is formed in action by the mixing of diluted sulphuric acid with a special alkaline solution. It is, of course, essential that where petrol, oil, or electric fires occur water should not be used : the oil will float about on the surface of the water in a flaming condition and spread the fire, and serious shocks may be given to persons using water in cases of electrical firing.

One of the most promising of modern fire extinguishers is that which employs methyl bromide, which is especially effective on petrol fires. It is portable, easily operated by hand alone, and the contents do not damage the most delicate machinery or fabric.

SANITARY FITTINGS

PART III.—TRAPS—TRAP-VENTILATING PIPES—SOIL PIPES

TRAPS

BY-LAWS governing the construction of drains and sanitary fitments provide for the trapping of all inlets receiving rain-, subsoil, and surface water, and the provision of a trap beneath soil and waste fitments.

A trap so provided may be described as a specially constructed chamber, retaining a quantity of water sufficient to prevent drain air passing through.

The most important points in connection with the provision of a trap are that it should have a small internal surface compatible with its size and type, and be smooth and self-cleansing. The body of the trap should hold just the sufficient quantity of water to submerge solid matters and prevent siphonage.

The water seal, or the depth of water between the throat of the trap and the water level, may vary between $1\frac{1}{2}$ in. in waste traps and 2 in. in soil fitments and drain traps, and $2\frac{1}{2}$ in. in intercepting traps, but should not be less.

The inlet to the trap of a water-closet or slop sink should be so shaped as to allow solid matters to fall directly into the water of the trap.

Trap Design

To comply with the above requirements, the trap should be of round-pipe shape, and be made with a smooth, non-porous, internal surface. It will then offer the least resistance to discharging matters. In comparison with the size of the fitment, the smaller the quantity of water the trap will hold, compatible with the size of the fitment and the maintenance of the proper water seal, the less the fouling surface presented, and the smaller the quantity of water required for resealing purposes. Traps for grease interception will not always comply with all of the above requirements, and must be selected on their individual merits for effectiveness and suitability.

Classification of Traps

For convenience of description, traps may be divided into three groups : drain traps for stoneware and cast-iron drainage ; tubular pipe traps for sanitary fitments ; and grease traps.

Drain traps may be divided into two types—intercepting and gully, and the outlets of these traps are usually restricted in shape to either P or S.

Traps cast integral with sanitary fitments, such as water-closets and slop sinks, and constructed of stoneware or enamelled fire-clay, are usually round-way pipe traps, P or S in shape.

The material of which a trap is made depends upon the type of trap required, and the fitment for which it is to be used. Traps can be obtained made of lead, copper, brass, cast or wrought iron, and of stoneware, or enamelled earthenware.

A variation of the round-way trap is the anti-D trap (see Fig. 1, page 443). It is claimed for the anti-D trap that it will successfully resist the action of momentum and siphonage, by means of an enlarged space in the form of a squared outlet. These traps may be obtained for use with urinals and sinks, and are also fixed in conjunction with valve closets.

Traps for sinks, baths, and lavatory basins are of the round-way type, fitted with cleaning screws at the bottom or side.

Grease traps are used in conjunction with sinks where large quantities of grease are likely to be discharged. They serve the purpose of retaining the grease, thereby preventing its passage into the waste pipe.

The shape of a round-way pipe trap may be varied according to the purpose for which it is required. In addition to the P and S traps, the following variety of shapes may be obtained: S, Q, bag, and running traps. (For further details, see pages 442 to 444).

Position of Trap

With certain exceptions, all sanitary fitments, such as water-closets, slop sinks, sinks, baths, urinals, lavatory basins, and bidets, should discharge directly into a trap fixed immediately beneath the fitment.

Traps to soil fitments, such as water-closets, slop sinks, and urinals, must either discharge into the drain direct, or into a soil pipe that is connected directly with the drain. A single urinal basin or stall must discharge directly into a trap, but where a range of stalls or basins is constructed, each stall or basin may discharge into an open and accessible channel formed and fixed immediately beneath, and thence into a trap fixed beneath the range.

If the urinal is fixed on a lower floor, the outlet stall can be arranged to be fixed over a drain trap of stoneware or cast iron, according to the construction of the drain. When fitted on an upper floor, the urinal should discharge into a lead trap, or a trap of any other suitable material as previously described, for subsequent discharge into a soil pipe and thence to the drain, and arranged so that means of access can be made to the trap.

Waste fitments, as sinks, baths, and lavatory basins, when fitted in ranges, may also discharge without the interposition of a trap into an

open channel fixed on the wall, or formed in the floor of the apartment, for discharge into a trap and thence to the main waste pipe.

TRAP VENTILATION

The duty of a trap is to provide an efficient barrier of water between the drain (or the soil or waste pipe) and the apartment in which the sanitary fitment is fixed, to prevent foul air entering the apartment. The provision of a trap alone will, under certain conditions, be all that is necessary, but there are always natural forces that tend to upset the efficiency of the trap, by lowering or destroying the water seal.

Loss of Water Seal

The causes of the loss of water seal in traps are siphonage, back pressure, absorption of gases through the water, evaporation, momentum, and capillarity.

The loss of the water seal in a trap by siphonage can be caused by a discharge from a fitting tending to create a partial vacuum in the discharge pipe, and so rendering the air pressure on the water in the trap greater than that in the discharge pipe, with consequent movement of the water in the trap.

In cases where two or more fitments are connected to one main discharge pipe, the discharges from a further fitting would, in passing the other branches, tend to push and compress the air between the end of the branch and the trap, sufficiently to force the water up into the fitment. A quantity would fall back into the trap, but in many cases enough would be blown out to unseal it.

The water seal of a trap offers very little resistance to pressure or partial vacuum. The actual resistance per square inch of water surface varies with the depth of the water seal, and the resistance to siphonage is approximately half the resistance offered to back pressure.

Back pressure, siphonage, and absorption of gases can be prevented by scientific ventilation of the traps and sanitary system.

The continuation of a soil pipe vertically upwards as a ventilation pipe may be all that is necessary where a single water-closet is fixed on a soil-pipe stack, and where the branch to the closet is a comparatively short one. Where closets are fixed in ranges, or one above the other on two or more floors, it is necessary to provide trap-ventilating pipes. This is the only way in which the water seal of a trap fixed under these conditions can be maintained.

The loss of water seal by momentum can be caused by the sudden or quick discharge of water into a trap attached to any sanitary appliance, the force due to the discharge being sufficient to unseal the trap, by carrying a quantity of water with it that would otherwise be in the trap. Momentum is possible where ventilation pipes are fitted.

The water seal of a trap can also be lost by the action of capillarity.

A piece of rag or flannel may get lodged over the crown of the trap, so that the water can rise up it and gradually run away down the waste or soil pipe.

Resistance to momentum and capillarity depends on the water seal and the shape of the trap, and may be prevented by fitting self-cleansing and suitably designed traps.

The evaporation of the water in a trap will also cause loss of water seal, and provide a free passage for drain air. This may happen in houses and other buildings that have been vacated for some time, and also in cases where a water-closet or gully is left unused, through the apartment being used for other purposes than those for which it was intended. Care should be taken to see that traps are always charged with water, and where gully traps receive only rain-water, it may be necessary in dry weather to do this by hand.

The provision of a trap-ventilating pipe is necessary not only to preserve the equilibrium of air pressure in branch soil and waste pipes, but also to ventilate the branch. The free flow of air through the system dries, and renders friable, the organic and putrescible matters which cling to the sides of the pipes, and, further, dilutes and eventually removes obnoxious gases from the system.

The unit of resistance of the water seal of a trap is much less than the unit of pressure of the atmosphere, and therefore the whole system must be designed so that absolute equilibrium of air pressure is maintained on each side of the water seal of a trap.

Trap-ventilating Pipes

In order that a trap may be efficiently protected against the loss of its water seal by siphonage, compression, and absorption of gases, the ventilating pipe provided must be connected to the trap or branch pipe in a suitable position. If the pipe is fixed in a position too near the crown of the trap, discharging matters will wash and silt up into the mouth of the pipe, and eventually clog it and render it ineffective ; alternatively, if it is fixed too far away from the trap its purpose will also be defeated.

The position laid down in by-laws for the connection of ventilating pipes is that such pipes shall join the trap or branch pipe not nearer than 3 in. to the crown of the trap, and not farther away than 12 in. The ventilating pipe must also join the branch soil or waste pipe in the direction of the flow.

Where two or more soil or waste fitments are fixed in a range or in ranges on upper floors, the trap-ventilating pipe from each trap should join a branch ventilating pipe, and thence into a main ventilating pipe. This pipe may be carried upwards separately, or it may be taken into the soil ventilating pipe in a suitable position above the highest fitting.

Single sanitary fitments, situated on alternate floors and discharging into one main soil or waste pipe, must also be provided with a main

ventilating pipe, which must be carried up separately from the lowest fitting to receive the branches from the fittings on the upper floors, and th en either be carried up separately as a vent-pipe, or be taken into the soil or waste ventilating pipe above the highest fitment.

If the vertical distance between the invert of the outlet of the lowest trap and the invert of the drain is less than 10 ft., the main ventilating pipe must be continued downwards, and be connected with the soil or waste pipe, or drain, at a point not less than 9 in. and not more than 2 ft. below the lowest branch. The object of this connection is to remove the possibility of air compression in the lowest branch due to the discharge from fittings above.

Sizes of Trap-ventilating Pipes

Ventilating pipes from waste-water fitments should be compatible with the size of the waste pipe and trap, but in any case should not be less than two-thirds the diameter of the branch or main waste pipe. From the traps of soil fitments, such as water-closets, urinals, and slop sinks, the size of the trap-ventilating pipe must not be less than 2 in.

Materials for Trap-ventilating Pipes

Installations of soil and ventilating pipes may be carried out completely in cast iron, copper, or lead. Alternatively, a combination of cast iron and lead is sometimes used, with cast-iron pipe for the main ventilating pipe and lead for the branches. Lead may be said to be very suitable for this purpose. It has a smooth bore that offers little or no resistance to the passage of air, and may be bent and fixed to accommodate almost any position. Copper, too, has the advantages of lead in every respect, and is rapidly gaining favour for this type of work.

SOIL PIPES

A soil pipe may be described as the continuation of a drain vertically or otherwise, above ground, to receive the discharges from sanitary appliances, as water-closets, slop sinks, and urinals.

Position and Construction

The position of a soil pipe, that is to say, whether it is to be constructed internally or externally to a building, depends upon the type and design of the building, and the position and type of the sanitary fitments. For example, it is not always desirable to carry a pipe on the front elevation of a building, even although it may be necessary to plan the sanitary apartments in the front of the building. In such a case it would perhaps be more desirable to carry the pipe down the building on the internal side of the front wall, and to take it through the wall and into the drain at a low level.

Alternatively, the sanitary apartments may be planned to abut on to an area in the centre or at the back of the building, in which case it may be possible to fix the soil pipe on the external wall without interfering with the architectural features.

In each and every case where a soil pipe is carried upwards to receive the discharges from sanitary fitments, it is necessary to continue the pipe vertically upwards above the highest branch, unreduced in diameter, as a ventilating pipe. For the purpose of ventilation, this part of the pipe, called the soil ventilating pipe, must be carried to a position where drain and soil-pipe air can be discharged so as not to cause a nuisance, or be a danger to health. This means that the soil ventilating pipe must be carried up to a point well above the eaves of a building, and clear of chimneys or any opening into the building. The top of the pipe must be fitted with a domical wire grating, with an aggregate area exceeding that of the pipe.

The point of connection of the soil pipe with the underground cast-iron or earthenware drain, as the case may be, should be at ground level. In cases where the drain is suspended along or across a basement, the point of connection would be at the bottom of the vertical up-shaft. The joint of a soil pipe to an earthenware drain should be underneath the ground surface, to prevent injury to the earthenware socket.

Lead soil pipes may be protected from injury at the base thereof, either by constructing the first length or lengths in iron, or by fixing a sheet-iron shield from ground level to a height of, say, 6 or 7 ft.

Materials, Jointing, and Fixing

Soil pipes are constructed of lead, cast iron, or copper, or of combinations of such materials.

The use of lead for soil pipes is well known. Care must be taken in its selection for use. It may be eminently suitable to receive the discharges from such sanitary fitments as urinals and water-closets, but where slop sinks are to be installed, the alternate discharges of hot and cold water into a lead pipe would cause the pipe to expand and contract, and in due course cracks would develop, with resultant failure.

The minimum weight of lead soil pipes should be 7 lb. per foot, and such pipes may be obtained in standard lengths of 10 ft. Joints in lead soil pipe must be what are known as wiped soldered joints. The pipes are fixed by means of pipe nails through strong cast-lead tacks soldered to the pipe at regular intervals, or, where fixed internally in chases formed in the brickwork, by lead collars soldered to the pipe, and resting on specially made brackets built into the wall.

Cast iron has many advantages for soil pipework. It is easily fixed, and may be obtained in standard lengths with the necessary fittings such as junctions and offsets, etc.

Properly caulked joints of gasket and metallic lead should be used,

with grooved or corrugated sockets, to prevent any creeping action of the jointing material due to expansion and contraction.

The substance of cast-iron pipe should not be less than $\frac{3}{16}$-in. metal, weighing 56 lb. per 6-ft. length. The weights of soil pipes are stipulated in the by-laws of most local authorities, and in London it is not permissible to use pipe of a less weight than that mentioned.

The internal and external surfaces should be protected from corrosion, either by galvanising, or by coating with a bitumastic such as Dr. Angus Smith's solution, or by vitreous enamelling. The internal surfaces should be especially smooth.

The fixing of cast-iron soil pipes can be carried out by nailing, through ears cast on to the collar of the pipe, into hardwood plugs driven into the wall, or they may be suspended on holderbats or hangers built into the wall. They should, in all cases, be fixed clear of the wall, so that attention can be given to the back of the pipe when recoating is necessary.

The use of copper soil pipe is becoming more general, especially in larger installations, where the soil pipes are fixed internally. It has the advantages of being light in weight, and it can be bent and fixed to suit most conditions. Copper may be successfully welded, either by the autogenous method, or by bronze welding, which allows the work to be easily prepared and fixed, and supersedes the use of compression joints for the purpose.

The weight of copper soil pipe per yard should not be less than, for 4-in. pipe, $11\frac{3}{4}$ lb., and for $3\frac{1}{2}$-in. pipe, $9\frac{1}{2}$ lb.

Copper soil pipe may be fixed by means of brass or gun-metal holderbats built into the wall, or by means of sheet-copper flanges welded to the pipe, and fixed to stays built into the wall.

ELECTRIC LIGHTING SCHEMES

IN order to design any lighting installation the number and size of the lamps required must be determined, as without this information the circuits and cables cannot be calculated. The principles upon which the lamp details are settled must, therefore, form the basis of every lighting scheme that is properly designed.

What Is Meant by Candle-power

The unit of all such calculations is the candle-power—the amount of light given out by a candle, made of specified materials and of a specified size, and all sources of light—sun power, arc lamps, incandescent lamps of various kinds, and so on—are compared on the basis of the candle-power they give out.

Measurements of Candle-power

A candle will naturally send out its light-rays in all directions—up, down, horizontally—and the light will differ in various directions. If the illumination given out in each direction is marked on a diagram so that the distance from the candle or the lamp represents the illumination in each direction, the curve thus obtained is called the polar curve for the lamp.

The average illumination measured horizontally is called the mean *horizontal* candle-power. Similarly, if the average figure in every direction is taken it is called the mean *spherical* candle-power, and it is this last figure that is most important, as in practice reflectors of one kind or another are used to reflect the light-rays, passing out in directions where they are not wanted, to directions where they are wanted The extent to which any reflector effects this purpose is a measure of its suitability and efficiency.

Intensity of Lighting

It will be realised that the illumination will change according to the distance of an object from the candle, and a measure of the intensity of the illumination is, therefore, necessary. This is the candle-foot or foot-candle, and is the intensity of light that is obtained at a distance of 1 ft. from the standard candle. It will easily be seen that the intensity of light varies as the square of the distance of an object from the light-source. If a square beam of light from, say, a candle flame is passing in any direction, of a size such that it will just light up an area 1 ft.

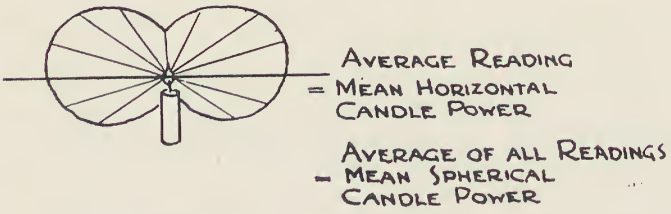


Fig. 1.—HOW CANDLE-POWER IS MEASURED

If the illumination given out in each direction is marked so that the distance from the candle or lamp represents the illumination in each direction, the curve thus obtained is called the polar curve for the lamp.

square at 1 ft. away, the beam will light up an area of 4 sq. ft. (2 ft. by 2 ft.) at a distance of 2 ft., or an area of 16 sq. ft. (4 ft. by 4 ft.) at 4 ft. away, and so on. The *total* amount of light remains unchanged, and therefore the *intensity* at 2 ft. away is only one-fourth that at 1 ft., and at 4 ft. only one-sixteenth that at 1 ft., i.e. the candle-feet obtained (the intensity of the light) will vary inversely as the square of the distance from the light-source.

The Total Output of Light—the Lumen

One further unit is required to represent the total output of light. This unit is the lumen, and is the volume of light falling on an area of 1 sq. ft. every point of which is 1 ft. distant from a unit candle. Such an area must be part of the surface of a sphere, and as the total area of a sphere of 1-ft. radius is $4\pi r^2$ or 12·57 sq. ft., it follows that the total output of the unit candle is 12·57 lumens.

We thus obtain three standard units for light measurements, viz. :—

(1) The unit source of light, or *candle-power.*

(2) The unit intensity of light, or *candle-foot* (the degree of illumination given by one candle at 1-ft. distance).

(3) The unit volume of light, or *lumen* (the amount of light given by the unit candle over an area of 1 sq. ft. at a distance of 1 ft. from the candle).

It will be easily seen that these three units can be connected up by simple formulæ.

(1) Illumination (in candle-feet) $= \dfrac{\text{candle-power}}{\text{distance from light-source squared}}$.

(2) Volume of light (lumens) $= 12{\cdot}57 \times$ candle-power.

(3) Foot-candles $= \dfrac{\text{total lumens}}{\text{area in square feet}}$.

Efficiency of Electric Lamps

In the earlier days of electric lighting the so-called "efficiency" of lamps was stated in the form of the watts required to give 1 candle-power, this being the mean spherical candle-power. Such a standard obviously represents the *inefficiency* of the lamp, as the more the watts per candle the worse the lamp.

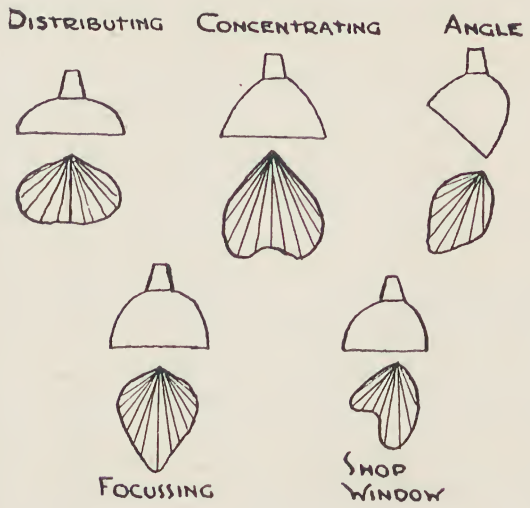


Fig. 2.—POLAR CURVES OF TYPICAL REFLECTORS

Showing how different types of reflectors enable light to be shone in the required direction.

Fig. 3.—HOW A LUMEN IS CALCULATED

This is the volume of light falling on an area of 1 sq. ft., every point of which is 1 ft. distant from a unit candle.

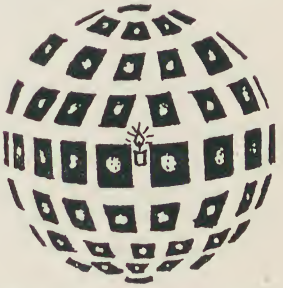


Fig. 4.—THIS SHOWS HOW THE TOTAL OUTPUT OF A UNIT CANDLE IS CALCULATED IN LUMENS

Great progress has been made in improving the effectiveness of the incandescent lamp, as will be seen from the following figures :—

Carbon-filament lamps : about 4 watts per c.p., or ·25 c.p. per watt.

Tantalum-filament lamps : about 2 watts per c.p., or ·5 c.p. per watt.

Tungsten vacuum lamps : about 1 to $1\frac{1}{4}$ watt per c.p., or 1 to ·8 c.p. per watt.

Tungsten gas-filled lamps : about $\frac{1}{2}$ to 1 watt per c.p., or 2 to 1 c.p. per watt.

These figures are only approximate, and vary considerably with the size and voltage of the lamp.

OUTPUT OF LUMENS

Type of Lamp	*Size*	*Voltage*	*Lumens*	*Lumens per Watt*
Pearl vacuum . .	25-watt	100 volts	223	8·9
,, ,, . .	25-watt	240 volts	193	7·8
Pearl gas-filled . .	60-watt	100 volts	720	12·0
Clear ,, . .	60-watt	240 volts	558	9·2
,, ,, . .	150-watt	240 volts	1,875	12·5
,, ,, . .	500-watt	240 volts	7,500	15·0
,, ,, . .	1,000-watt	100 volts	18,700	18·7

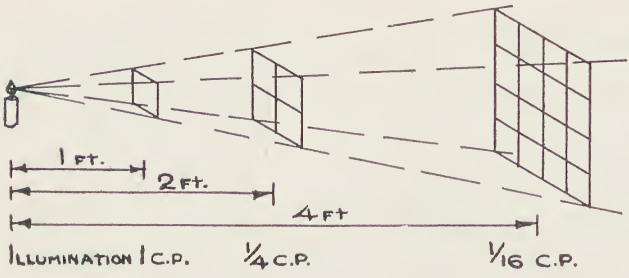


Fig. 5.—CALCULATING THE INTENSITY OF LIGHT

The candle-foot or the foot-candle is the intensity of light that is obtained at a distance of 1 ft. from the standard candle. It will be seen that the intensity at 2 ft. away is only one-fourth that at 1 ft., and at 4 ft. only one-sixteenth that at 1 ft.

A much more satisfactory measure of the efficiency of the lamp is the number of lumens given per watt, and this figure is a true measure of the efficiency. It varies considerably according to the size and voltage of the lamp, modern gas-filled lamps varying from 7 lumens per watt for small-size 200-volt lamps, up to nearly 20 lumens per watt for the largest sizes of lamps made. The actual lumens given by each size and type of lamp at various voltages can be obtained from the lamp-makers' catalogues, but the Table on page 583 gives a few typical figures. The examples given have been chosen to illustrate how the lumens-per-watt figure varies with the size and voltage of the lamp.

First Step in Designing Lighting Installation

Having thus obtained basic data, it is possible to proceed with the design of a lighting installation.

The first step is to decide the intensity of light required, and whether this is to be uniformly distributed over the area to be lit, or concentrated at special points. This depends on the way the light is to be used. To take an extreme case, of a laboratory used for microscopic research, the light must be almost entirely concentrated at very small local areas, and a large number of small local units is required. On the other hand, in a lecture-hall, the entire floor area must be evenly lit, and the less the variation in light intensity between different points the better the scheme. In other cases, such as some engineering shops, the best result is obtained by combining good general lighting with special local lighting at particular points, such as on the actual tool or piece of work.

Points to Watch

In almost every installation the points to be taken into consideration are :—

(1) Adequate illumination—which may be required on a horizontal or vertical surface, and may be general or local.

(2) Avoidance of direct glare from lamps.

(3) Avoidance of indirect glare by reflection from polished or light-coloured surfaces.

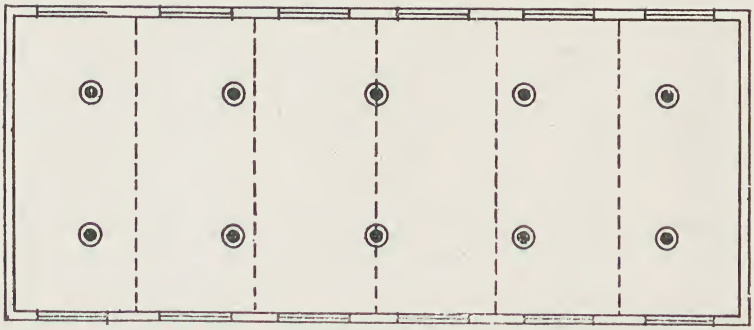


Fig. 6.—ARRANGEMENT OF LIGHTING UNITS (1)
This shows the theoretically correct spacing in the ceiling of an office.

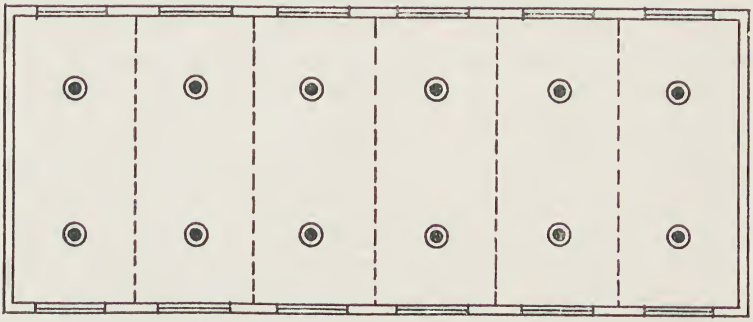


Fig. 7.—ARRANGEMENT OF LIGHTING UNITS (2)
The irregular spacing shown in Fig. 6 would give an unsatisfactory appearance, and the fittings should be re-arranged to suit the beams, two extra lighting units being added.

(4) Avoidance of excessive shadows—or rather of shadows in wrong places.

(5) General appearance of the complete scheme.

(6) Future maintenance of the installation.

The relative importance of these points differs greatly for different conditions, and experience, combined with judgment and common sense, is required to decide whether one consideration is more important than another. A few examples will indicate the position.

Glare—Direct or Indirect

It is almost always necessary to arrange the lighting units to avoid glare, direct or indirect. In fact, almost the only type of lighting for which this is not essential is for flood-lighting of buildings and similar quite abnormal work. Direct glare can be avoided by fixing the fittings in positions where the lamps are not directly visible, or by the use of suitable reflectors or fittings.

Indirect glare is sometimes more difficult to avoid. The ill-effects are similar to those of direct glare, viz. eye-strain and loss of visibility, due to the excessive intensity of the light at a particular point or small area. The evil can frequently be cured by altering the angle of the working surface.

Shadows

Shadows cannot and need not be entirely avoided. The need is to avoid their occurring in wrong places, as, for example, by having a light-source so placed that the worker is "in his own light," as it is usually expressed. Such shadows as occur should not be too harsh, nor of such intensity as to prevent any object being clearly distinguishable from its shadow. Within such limits shadows are by no means undesirable. A room nearly free of shadow, as can be arranged with indirect lighting, is apt to be dull and uninteresting, and certainly requires much higher illumination if it is to seem cheerful and bright than one in which there is a reasonable amount of shadow.

General Appearance

The general appearance of the completed scheme is of great importance. The spacing of the fittings must often be arranged to suit constructional details, as, for example, when fittings must be hung from tie-bars of a machine shop because no other suitable supporting position is available. In other cases they must be arranged to fit in with the spacing of beams in an office ceiling. In some cases this consideration is of extreme importance, particularly in such buildings as churches, public halls, and so on.

Figs. 6 and 7 illustrate how the lighting units must be arranged to suit the spacing of ceiling beams in the diagram shown representing the ceiling plan of an office. The theoretically correct spacing should be as shown in Fig. 6, but the irregular spacing relative to the beams would give a most unsatisfactory appearance, and the fittings should therefore be re-arranged to suit the beams, and two extra lighting units added to give a more pleasing distribution, as shown in Fig. 7.

Some consideration must also be given to the type of fitting or lighting unit. Large, single-lamp-unit fittings that would be ideal for a lofty factory building would be quite out of place in a church, where fittings with several small lamps would be more suitable to the building even though some loss in efficiency should result from such a scheme of lighting.

Maintenance Details

Maintenance is also of prime importance. It is no use lighting a very lofty building with very few and very large lighting units, as might be theoretically correct, if there is no means of access to the lamps for

renewal and cleaning. Facilities for easy and effective cleaning are particularly important, as the efficiency of the whole scheme will fall off rapidly if fittings and lamps are not kept clean, and for this reason reflectors, when used, should have smooth, polished surfaces that can easily be washed.

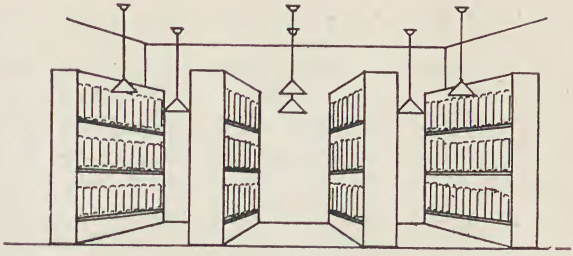


Fig. 8.—How pendent lights should be arranged for illuminating bookshelves

As a rule these do not require more light than is necessary to read titles or labels, and detailed designing is not called for.

Illumination of Vertical Surfaces

Apart from the flood-lighting of buildings, the need for illumination of vertical surfaces is confined in general to a few special cases. Of these the most important is the lighting of pictures, diagrams, or charts, and so forth, hanging on walls. Occasionally, special lighting is required for vertical filing-cabinets, for bookshelves, storage bins, etc., but as a rule these do not need more light than is required to read titles or labels, and detailed designing is not necessary. Ordinary pendants or brackets spaced at reasonable distances provide all that is required.

The lighting of ordinary charts and plans hanging on walls can be carried out either by tilting ordinary-type reflectors, or by the use of special angle reflectors, as indicated in Fig. 9.

Picture lighting is a much more complicated problem and, whilst it is possible to apply the principles of ordinary illumination calculations to ensure adequate lighting, the difficulties of applying the light to obtain satisfactory results are very great. The glazing over the picture, or its natural glossy surface, gives varying reflections from different angles, and it is almost impossible to obtain really efficient lighting without some special system of indirect reflectors or flood-lighting through distant wall or ceiling panels. Such schemes can rarely be applied to existing buildings, the structure of the building needing to be designed to provide suitable sources of light.

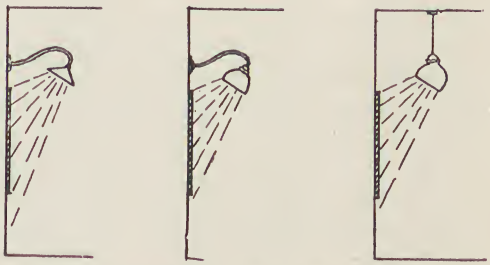


Fig. 9.—Lighting for charts or plans hanging on walls

This can be carried out by tilting ordinary-type reflectors, or by the use of special angle reflectors, as shown.

Horizontal Surfaces

The problem most usually needing solution is the lighting of horizontal areas, such as desk surfaces in offices, schools, etc., floor areas in shops, halls, factories, churches, and similar buildings, and the general lighting of workshops or domestic rooms. Each class of building needs its own kind and intensity of illumination, and the notes here deal with the problem in a general way that applies to all such schemes.

Intensity of Illumination

The first point to be decided when designing an installation is the intensity of illumination required, and this naturally varies for different buildings. The following examples will give a general guide as to the standards desirable, and the results that should be attained :—

Churches . . .	4 to 5 candle-feet.
Club-rooms, halls, etc.	5 to 6 candle-feet.
Shops . . .	From 5 to 15 candle-feet, according to locality, class of goods sold, etc.
Shop windows . .	10 to 50 candle-feet, also according to locality, etc.
Drawing-offices .	20 to 30 candle-feet or more.
Library reading-rooms	8 candle-feet.
Hotel reception rooms	6 to 8 candle-feet.
Office areas . .	5 to 6 candle-feet if local lighting is also provided. 8 to 10 candle-feet if only general lighting is provided.
Textile factories .	5 to 10 candle-feet, according to class of work carried on.
Machine shops . .	For rough work, 6 to 8 candle-feet. For fine work, 10 to 20 candle-feet.
Corridors, staircases, etc.	2 to 3 candle-feet.

It will be seen that the range of illumination is very considerable, but from the examples given the intensity of the light desirable in other cases can probably be estimated.

Total Quantity of Light Required

Having decided the intensity of light required, the total quantity can be ascertained by multiplying the total floor area of the room or building to be lit by the candle-feet considered desirable, based on the data given above. The result will give the total lumens required for the total area. This figure is the actual effective volume of light required, and to this must be added such margin as is required to make good losses in reflection, absorption in wall surfaces, etc., and also an allowance to cover the gradual diminution in the light due to ageing of lamps, deposit of dust on fittings and lamps, and finally due to the losses in the fittings themselves. The cumulative effect of all these losses is a formidable total, and even with a well-designed scheme and favourable conditions these causes may involve a total loss of 50 per cent. or more of the actual light given out by the lamps.

The following examples indicate the general position.

Loss of Light by Reflection from Walls and Ceilings

Very light colours	25 to 40 per cent.
Fairly light colours	35 to 50 per cent.
Fairly dark colours	50 to 70 per cent.

This factor is not of great importance if the room to be lit is of considerable dimensions in proportion to its height, i.e. if the length and width are several times the working height. This is usually the case with most large stores, factories, or offices, and for such areas an allowance of 10 per cent. to 15 per cent. for losses due to reflection or absorption in walls and ceilings will be sufficient.

Losses Due to Fittings

Good-quality dispersive reflectors	15 to 20 per cent.
Enclosed unit fittings	30 to 40 per cent.
Opal-glass bowl fittings	40 to 50 per cent.
Mirrored (opaque) bowl	50 to 70 per cent.
Losses due to dusty fittings	From 20 to 25 per cent. and upwards

It is rarely possible in practice to calculate any of these losses in advance with close accuracy. At the date when the lighting installation is being designed, the exact colours of walls, for example, are frequently undecided. The care with which the installation will be maintained cannot be known, and other factors of a similar kind make close calculation difficult or impossible. Frequently the type of fitting to be used may be modified at the last moment on account of cost, delivery, etc.

In designing the installation it is therefore usually impossible to do more than calculate the net or effective lumens, and to multiply this by some factor suitable to the probable circumstances. This is not likely to be less than $1\frac{1}{4}$ to $1\frac{1}{2}$, and it is usually best to allow $1\frac{1}{2}$ to twice the net lumens in preliminary calculations, even if conditions are likely to be of a satisfactory character.

Lamps can easily be cut down later on if larger than necessary, but cannot be increased if the wiring is too small due to under-estimating the lamp sizes.

Spacing of Lighting Units

The final step is to decide how to utilise the total lumens thus found to be necessary for adequate illumination, i.e. to decide on the number and spacing of the lighting units. This also depends on several considerations, the two decisive points being :—

(1) Distance apart to ensure even illumination.

(2) Distance apart to suit method of fixing (on tie-bars, roof trusses, etc.), or to suit architectural features (spacing of visible beams, ceiling decoration, etc.).

Types of Reflectors Available

Of the above two items, the first is the more important. A fairly wide latitude is possible, due to various types of reflector being available,

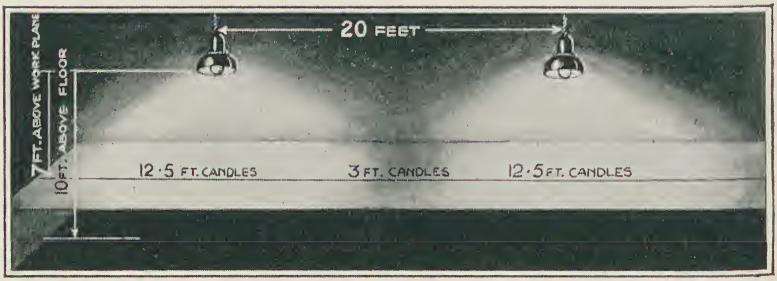


Fig. 10.—How lighting units should be spaced (1)
This shows the units spaced too far apart, giving uneven illumination.

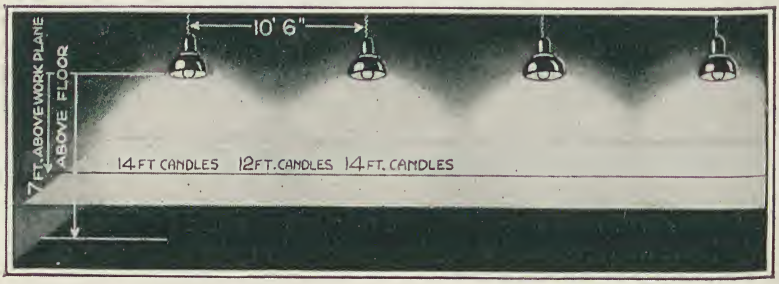


Fig. 11.—How lighting units should be spaced (2)
Here, the lighting units are correctly spaced, resulting in even illumination.

some designed for concentrating the reflected light into a fairly narrow compass (suitable for high buildings), and others for diffusing the light over a wide area (suitable for positions where the ceiling height is not great).

Fig. 2 shows several types of reflectors with their polar curves, which indicate how the light from the lamp is concentrated or distributed by the reflector.

Use of Reflectors

Concentrating-reflectors are usually employed for special work, such as window lighting, whilst diffusing-reflectors are more suitable for ordinary, general lighting. With such reflectors, to ensure even lighting, the installation should be planned so that the distance between adjacent reflectors is not more than $1\frac{1}{2}$ to $1\frac{3}{4}$ times the distance from the reflector to the surface to be lit.

Thus, if an office is 12 ft. high, the reflector can be hung with the lamp about 1 ft. down from the ceiling, and the office desks will be about 2 ft. 6 in. from the floor. The distance from the lamp to desk will thus be about 8 ft. 6 in., and the spacing of the fittings should be not more than $1\frac{1}{2}$ to $1\frac{3}{4}$ times this, i.e. from 12 ft. to 15 ft. apart.

Fig. 10 shows the effect of fixing the lighting units too far apart, resulting in uneven and patchy lighting, and Fig. 11 the improvement resulting from fixing the units at the correct spacing. The size of the lamp units can obviously be reduced in this case to give the same average illumination as is obtained in the former scheme.

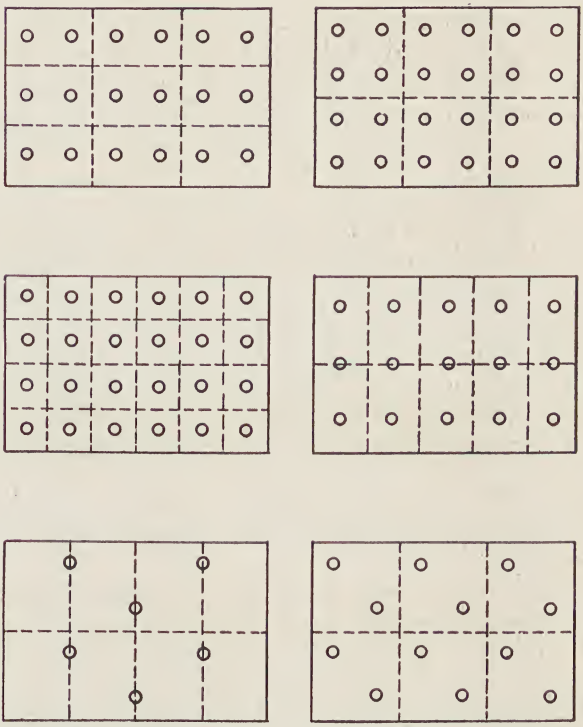


Fig. 12.—SIX DIFFERENT SCHEMES, EACH WITH A SYMMETRICAL ARRANGEMENT OF THE FITTINGS, TO SUIT DIFFERENT ARRANGEMENTS OF THE CEILING DESIGN (INDICATED BY DOTTED LINES)

Spacing to Suit Architectural Features

Having thus decided the approximate spacing to suit the height of the building, a further adjustment is frequently necessary to suit architectural features. Fittings in an office or shop, for example, must be arranged to fit into the spacing of windows or ceiling panels, or to form features in some scheme of decoration. In factories the fittings must frequently be supported from roof-ties, and should in any case form a symmetrical layout in relation to the roof construction.

Considerations of this character may involve a substantial alteration in the design of the installation, but usually the adjustments required are not sufficient to spoil a scheme. The margins allowable, due to the use of various types of reflectors, or to adjustments in the suspension heights, are in almost all cases wide enough to rectify any errors due to enforced alterations to the theoretical design to suit architectural features.

Alternative Arrangements

In most buildings several alternative arrangements of the lamps will be found possible, each of which will give reasonably satisfactory results.

Fig. 12 shows six different schemes, each with a symmetrical arrange-

ment of the fittings, to suit different arrangements of the ceiling design (indicated by dotted lines), and any one of these might be suitable, according to the calculated ratio of working height to spacing distance. The scheme most suitable for all the factors involved must be selected.

Number and Size of Units Required

Having fixed on the arrangement and spacing of the lighting units, the positions can be marked out on the plan of the building, and the total number of units required for the complete area is then known.

By dividing this number into the total lumens required, as calculated earlier, the lumens that must be given out by each unit are obtained, and the size of lamp to be used is then found by reference to a lamp catalogue which gives the lumens per lamp for various sizes and voltages. The design of the installation is thus completed, the spacing, type, and size of the lighting units all having been calculated.

The Procedure—Step by Step

Summarising the steps in the design of the lighting scheme the procedure is thus :—

(1) Decide the intensity of illumination (candle-feet) required to light the area.

(2) Measure the total floor area to be lit.

(3) Ascertain the total quantity of light required (net lumens) by multiplying the candle-feet by the floor area.

(4) Correct this net figure to allow for losses in reflection, absorption in walls and ceilings, dust on fittings, etc.

This correction will mean increasing the net lumens 1½ to 2 times.

(5) Decide the spacing of the lighting units to suit :—

(*a*) the height of the room,

(*b*) the architectural features,

and thus settle the number of lighting units to be used.

(6) Ascertain the lumens required per unit by dividing the total lumens (item 4) by the number of units (item 5).

(7) Select the size of lamp required that will give out the lumens as calculated (item 6).

DRAINAGE OF BUILDINGS

PART VII.—COUNTRY HOUSES, INSTITUTIONS, FACTORIES, AND ESTATES

"EVERY Irish gentleman builds his house *near* a good site," was the explanation once given to the present writer for the somewhat unfortunate position of certain buildings.

The same may be said for many houses in England, erected in beautiful surroundings but at levels and in positions where the difficulties of drainage, and consequently the convenience and sanitary condition of the building, are affected seriously. It will generally be found in such cases that a slight change in position or in level would have made a very great difference (Fig. 1).

Special Conditions to be Considered

In the drainage of country estates, houses, and public institutions there are special conditions which should be considered at the outset—problems of land drainage, flooding, sewage disposal, avoidance of the pollution of sources of water supply, the requirements of agriculture river authorities, fishing interests, and amenities may arise. It is necessary to dispose of the sewage, a matter which often presents greater difficulties than might at first be imagined.

Pollution of Water Supply

The drainage of a house or collection of houses situated, for example, in the Thames valley must of necessity find its way ultimately into some water-course forming the natural drainage channel of the district, the flow from which must eventually enter the Thames. As a very large proportion of the water supply of London is drawn from the Thames, it follows that there are stringent rules against pollution, and that the officers of the Thames Conservancy are always actively engaged in their enforcement. Thus it may happen that the owner of a new property is confronted with the unexpected difficulty of compliance with the demands of the River Authority, which are to the effect that all sewage discharged shall have been purified to a high standard even though the property may be remote from the river and the sewage subjected to natural purifying agencies in its travel along the intervening water-courses.

In one case within the writer's experience a small estate was completely surrounded by lands belonging to a most important authority.

The only possible outlet for the sewage was into a ditch on that property, in which there was no water except in times of heavy rainfall. The legal position was such that the owners of the outside property could not object to the discharge of the rainfall run off, or to clean water, into their ditch, but the discharge of anything in the nature of sewage was forbidden. Purification works of a very elaborate nature were therefore required (Fig. 2).

A building in the country is frequently dependent upon its own well for water supply, and if the property is of small extent in a chalk district a problem of some difficulty may be presented by the fact that pollution of a well in the chalk is liable to occur when sewage or even purified sewage effluent can find its way into the chalk fissures. When the chalk is exposed at the surface of the ground the drainage problem may be one of considerable difficulty (Fig. 3).

How to Avoid Unnecessary Expense

The problems which may occur in the drainage of isolated buildings and establishments are many, but they can all be solved if proper attention is given to them at the outset, and it is only when there has been failure to appreciate the requirements of the situation that the unexpected difficulties, which often involve expense, occur. When a property is laid out or a building designed without preliminary consideration of the drainage, great and unnecessary expenses are often incurred, and it is therefore most necessary that the architect and the sanitary engineer should work together from the start. The term *sanitary engineer* is often misused, being adopted by builders, estate agents, manufacturers, and others, whose knowledge of the subject either is of a most elementary kind or relates to some special branch.

Choice of Site

In many cases, houses have been built upon damp sites, and sometimes on land which is liable to floods, when a dry site has been available close by. Great trouble is experienced owing to dampness and to flooding. The rise of the water level may not be such as to cause water to enter the building, but it may be such as to render the house drains inoperative at certain times, and to cause other troubles which could have been foreseen and avoided (Fig. 4).

The first consideration in any drainage scheme is the outfall. It is necessary to decide where the drainage shall be discharged, and until this matter has been settled it is impossible to decide upon the best and most convenient method of drainage, and upon the best layout of the system.

Drainage of the Site

Among the first essentials is the need that the house shall be dry; if the site is not dry it must be made so. If it is situated on ground

Fig. 1.—A HOUSE SHOULD BE SITUATED ABOVE THE HIGHEST FLOOD LEVEL

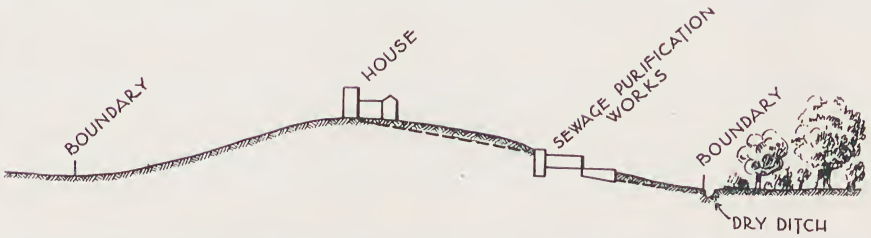


Fig. 2.—SMALL ESTATE SURROUNDED BY PRIVATE PROPERTY

Sewage effluent discharged into dry ditch outside estate had to be purified with great care in order to avoid legal action.

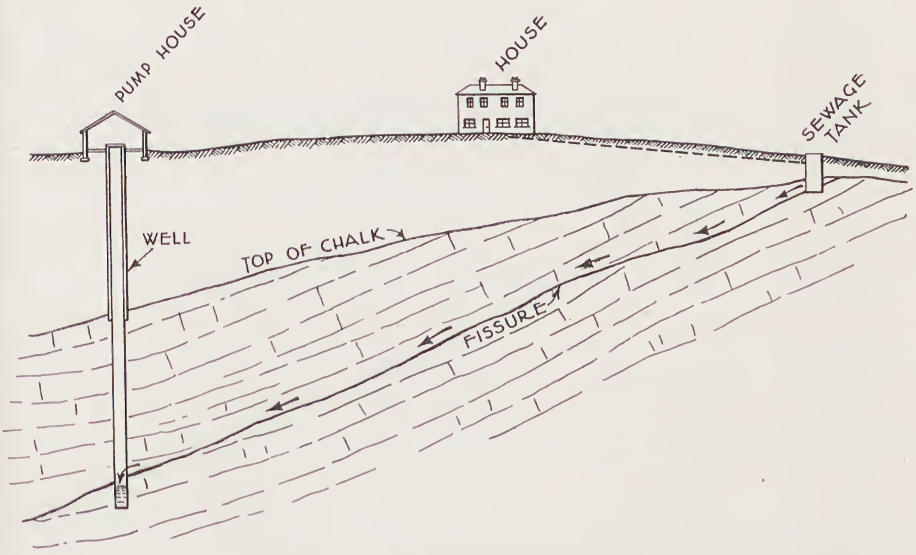


Fig. 3.—SEWAGE FROM LEAKING TANK PASSING DIRECT TO WELL THROUGH A FISSURE

The pollution of wells by sewage effluents improperly discharged is common and is very dangerous.

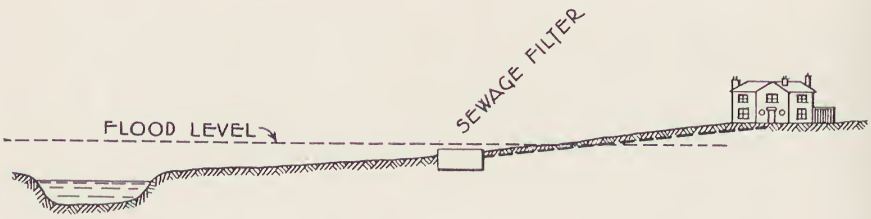


Fig. 4.—SEWAGE PURIFICATION WORKS RENDERED INOPERATIVE AND FLOW IN MAIN DRAIN STOPPED OR IMPEDED BY RISE OF FLOODS, THE HOUSE ITSELF BEING WELL ABOVE FLOOD LEVEL

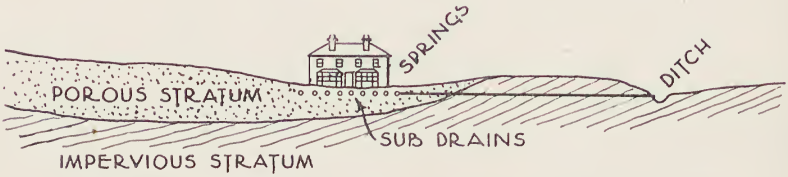


Fig. 5.—REMOVING LAND WATER FROM DAMP SITE

Water carried away to suitable outfall after removal from site by means of open-jointed agricultural pipes laid in trenches filled with gravel.

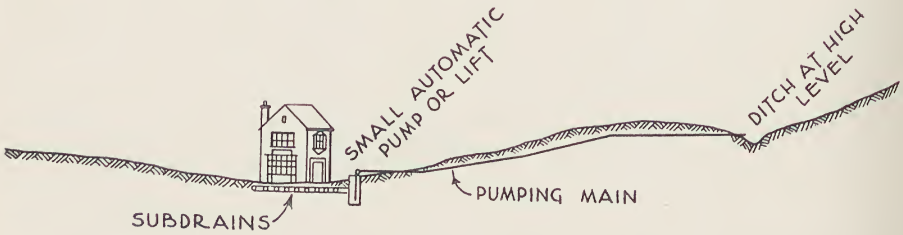


Fig. 6.—WHERE A GRAVITATION DRAIN IS IMPOSSIBLE, THE GROUND WATER LEVEL MAY BE KEPT LOW BY MEANS OF AN AUTOMATIC PUMP OR LIFTING DEVICE

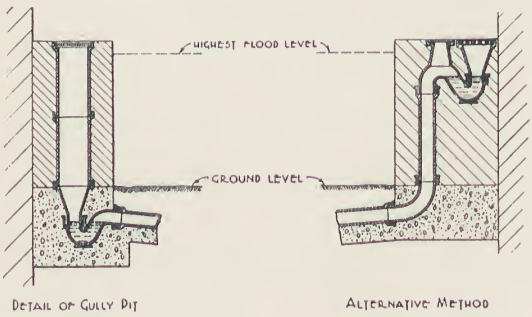


Fig. 8 (*left*).—DETAIL OF GULLY PIT AND ALTERNATIVE METHOD OF CONSTRUCTION

which is within the reach of floods, even if these floods occur at very rare intervals, special steps must be taken for its protection, although, speaking generally, such sites should be avoided, and they should be occupied only when the possibilities of flooding have been fully realised and when special steps for the protection of the property can be taken. In some cases, either from necessity or from choice, buildings are erected in positions where flooding will at times occur.

It should be understood that in the drainage of a site the possibilities are limited only by the expense. Water can be drained away from a wet site, leaving that site dry and suitable for habitation. Generally this can be effected by gravitation (Fig. 5), but where this is impossible, and the conditions warrant the expense, there is no difficulty in pumping the water away. Where the quantity of water is small or the accumulation slow, such pumping may not be a very serious matter ; the water may be drained to an underground sump, and may be lifted automatically as it accumulates by simple devices which have been described in preceding articles. Naturally it is not desirable to place a house on a site which has to be drained by pumping (Fig. 6), but when a site is found to be wet where a building exists it is always possible to deal with the matter by drainage.

Sewage Drainage in Flood Areas

There are many buildings which exist in positions where the drainage of the sewage by gravitation is also impossible, and under such circumstances the sewage must be lifted. In other cases the sewage can be dealt with by gravitation, but in times of flood it may be impossible, and in that case special steps must be taken to make possible the discharge of sewage at a higher level during flood times. The following examples of riverside buildings illustrate these possibilities.

In the first case a house was built on a site where flooding occurred periodically to a level of 4 ft. above the ground surface. The house was therefore built upon arches and piers, so that the ground-floor level was well above flood level. In times of flood the house was isolated, and could be approached only by boats. The drains were constructed of iron pipes with watertight hatch-box manholes, and discharged into ejectors which lifted the sewage to a public sewer situated at a higher level in an adjoining road. The soil pipes were connected to the drains in the usual manner, and the other waste pipes, from sinks, baths, etc., discharged into trapped gullies at ground level, but in order that the flood water might be excluded from the gullies each one was surrounded with a watertight wall of brickwork carried up to a level above that of the highest flood. Thus, although the drains and open gullies were below the flood water they were unaffected, and the house could be inhabited at all times (Fig. 7).

It will be obvious that a trapped gully situated at the bottom of a

shaft 4 ft. deep cannot be cleaned very easily, and that it would be better in such a case to fix the gullies at a high level, with vertical drop-pipe outlets, provided with cleaning-eyes (Fig. 8).

In another case, where no sewer existed, it was necessary to install filters for the purification of the sewage, and to arrange the drains and the filters in such a manner that they would not be affected by floods. In this case the waste pipes were connected to ventilated sealed gullies having watertight covers which were bolted down on to their seatings. The drains and manholes were made absolutely watertight, and so were unaffected by the floods, and all sewage was lifted to purification works which were situated above flood level (Fig. 9).

Another possibility is that of placing the filters or other purification plant at such a level that they will work by gravitation in normal times, and making provision against the flooding of the works by means of walls and valves for the exclusion of flood water, also making provision for the storage of effluent and for pumping it away at flood times (Fig. 10).

Drainage of Houses in the Country

There are innumerable possibilities and requirements for the drainage of houses or small communities in the country. Large or small dwelling-houses, cottages, farms, hospitals, schools, institutions, and factories come under consideration, and the very difficult and important question of the drainage and purification of trade wastes is not to be avoided. The drains may have to discharge on to land remote from streams, into streams or rivers, tidal estuaries, lakes, or into the sea. The purification required may have to vary within the widest limits. The actual methods of drainage in town or country do not differ materially, and as these matters have been dealt with in preceding articles, it is unnecessary to repeat what has been stated in relation to methods and principles. The method of dealing with the sewage is, however, entirely different where discharge into public sewers is impossible.

Methods of Sewage Disposal for Country Houses

For the ordinary country house, the method of disposal of the sewage must be dependent upon many factors, such as the nature of the destination of the discharge.

In a discussion relating to sewage disposal at the Institution of Sanitary Engineers, Dr. J. J. Paterson mentioned the case in which the sewage of a large town was disposed of by pumping it into a large depression which existed in a gravel bank in the Thames valley. The gravel acted as an efficient filter, and although there were millions of gallons of sewage passing into this gravel daily, the most careful search by experts had failed to find any sign of pollution in the river. The case is exceptional, but it shows the desirability of making a careful examination of

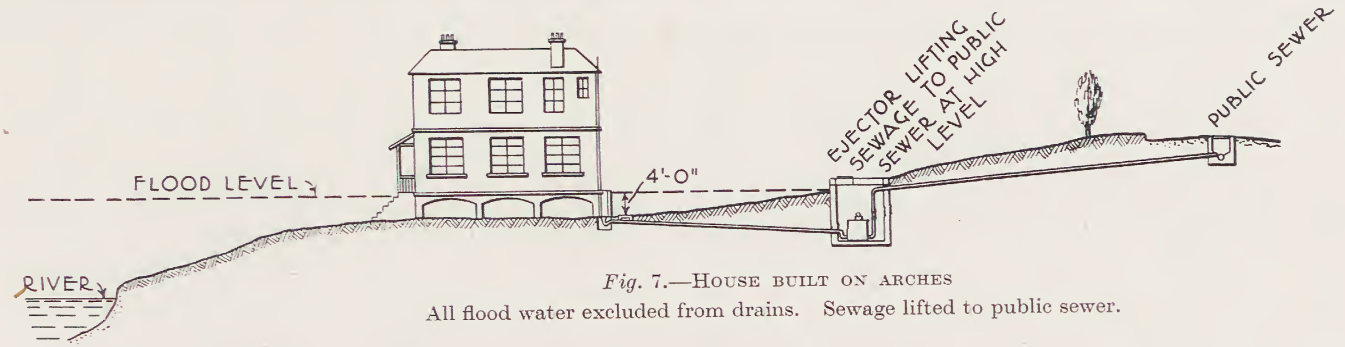


Fig. 7.—House built on arches

All flood water excluded from drains. Sewage lifted to public sewer.

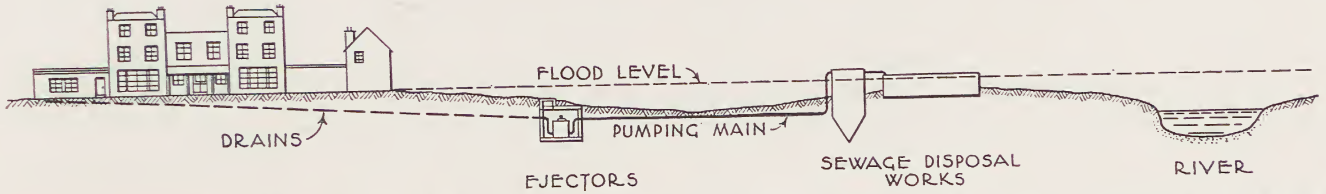
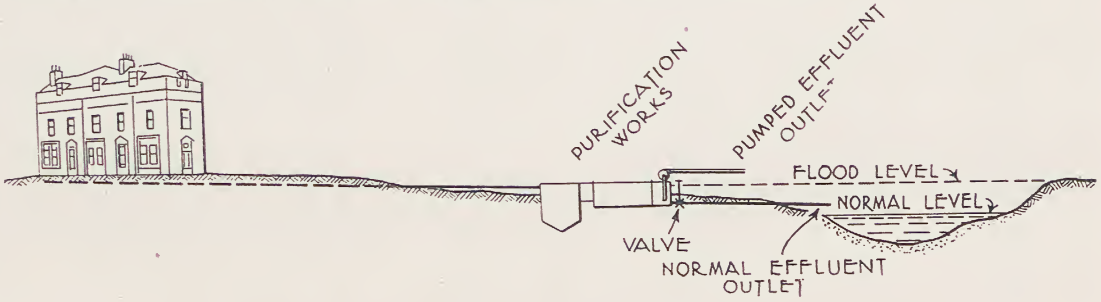


Fig. 9.—House with watertight drains and manholes and sealed gullies—drains running to ejectors by means of which all sewage is lifted to purification works above flood level

Fig. 10 (*right*).—Purified sewage effluent by gravitation under normal river conditions, but pumped to discharge at higher level when the river is in flood



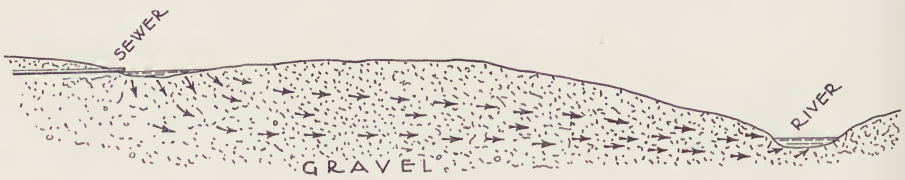


Fig. 11.—SEWAGE PURIFIED BY NATURAL FILTRATION THROUGH A GRAVEL FORMATION

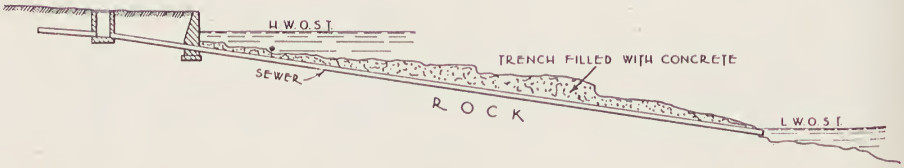


Fig. 12.—SEA OUTFALL SEWER FOR SMALL BUILDING ESTATE

A sea or river outfall for sewage may be possible under certain conditions, but generally some form of treatment will be necessary, the degree depending upon local conditions.

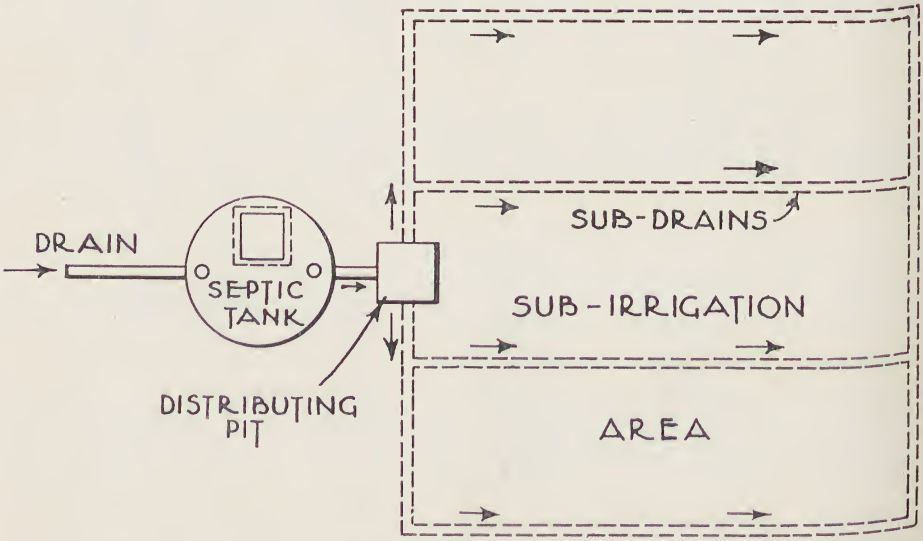


Fig. 13.—SUB-IRRIGATION SCHEME FOR COUNTRY HOUSE

the ground before adopting any expensive form of sewage treatment (Fig. 11).

It would be entirely incorrect to say that in a well-designed system the average country house is provided with tanks and filters ; such may or may not be necessary.

Sewage Disposal at the Seaside

For the drainage of a small building estate on the north-east coast, the present writer carried a small outfall sewer out to sea (Fig. 12). A trench was cut through the rock between high and low water, and 6-in. stoneware pipes were laid in the trench, which was filled with concrete, the surface following the contour of the rock. The quantity of sewage being small, and the currents being such as to carry the sewage away where it would receive natural purification in the sea, the method was considered suitable on a wild coast, but it must be observed that although such outfalls are often provided for houses and small communities situated by the sea or on tidal estuaries, it would be safer and better to provide some method of purification, and the degree to which purification is necessary will be dependent upon conditions, and may vary from simple screening, interception of solid matter in tanks, filtration, or other biological purification, and sterilisation of the effluent by means of chlorine where there is danger to bathers or risk of shell-fish contamination.

Sewage Disposal by Sub-irrigation Drains

Many houses in the country dispose of their sewage by means of sub-irrigation drains which, if laid on a suitable soil, will carry sewage from which the solids have been removed and distribute it below the surface of the ground in such a manner that it is purified before it reaches the underground water-bearing stratum. In such a case the sewage is allowed to pass through a tank in which the solids are intercepted before it reaches the sub-drains. This method is very useful for small properties situated on porous or gravelly strata, but is unsuitable for impervious soils such as clay (Fig. 13).

Use of Soakage Pits

Another simple method of dealing with a small quantity of sewage is that of allowing it to pass into a soakage pit constructed in porous ground, but the method is suitable only under certain conditions, where the sewage can pass away freely into a stratum, remote from wells and sources of water supply, in which it will receive efficient purification. Such pits should not be made in chalk or fissured rock, because the sewage can pass without purification into the water-bearing stratum, and may pollute wells (Fig. 14) or springs at a considerable distance. The fact that the porous ground in which the soakage pit is sunk may become

clogged with sewage, rendering the pit unserviceable, is very important, and is apt to lead to disappointment and unexpected expense. It is therefore well worth while to consider the matter very carefully before adopting such a system.

Cess-pits

A great deal of trouble and disappointment may occur where the sewage of a house is taken into a cess-pit. In these days many rural authorities require that all cess-pits shall be watertight, and they sometimes undertake to empty these pits, agreeing to do so free of charge. Experience has proved, however, that the task of emptying all the cess-pits in the district, so as to prevent them overflowing, is a practical impossibility. Seeing that the ordinary cess-pit will become full in a few days, no reliance should be placed on this method.

There are, however, various possibilities worthy of consideration. In one case the sewage of a country house was carried to a large cess-pit. The sewage was pumped from the cess-pit every day in order to prevent an overflow. Inspection proved that the land was of such a nature that sub-irrigation was possible. Thus, instead of pumping the sewage into trenches at the surface of the ground, where it was highly objectionable, the liquid was made to overflow into open-jointed irrigation pipes laid below the surface of the ground, so that no pumping was required, and there was no further nuisance from sewage exposed in the open air (Fig. 15).

Sewage Purification

On some estates, each cottage or building has its own cess-pool and other primitive arrangements for the disposal of sewage, with the result that there is a nuisance from smell and probably stream pollution (Fig. 16). Further, there is continual waste of labour in the emptying of these pits and in the disposal of the material extracted. In such a case it is generally possible to lay a main drain to which all the houses can be connected, and to convey all the sewage to a suitable point, which is generally at the lower end of the estate (Fig. 17). Here it is possible to construct a tank which will intercept the solid matter before the sewage becomes septic, and to treat the sewage on a filter which will be practically automatic in working, while the sludge that has been intercepted can be retained in the tank until it has been purified by natural organic and chemical action, and from which it can be drawn periodically in an innocuous condition in which it is suitable for use as a fertiliser.

Sewage Filters

In the case of very many country houses, it is necessary to purify the sewage to a high standard before it is discharged into any stream or river. It cannot be said that there is any general process applicable to

Fig. 14.—POLLUTION OF WELL BY SOAKAGE PIT

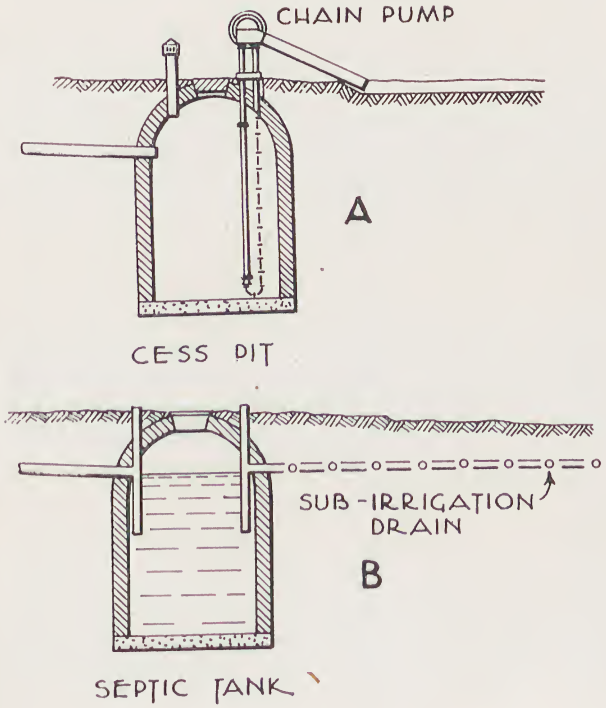
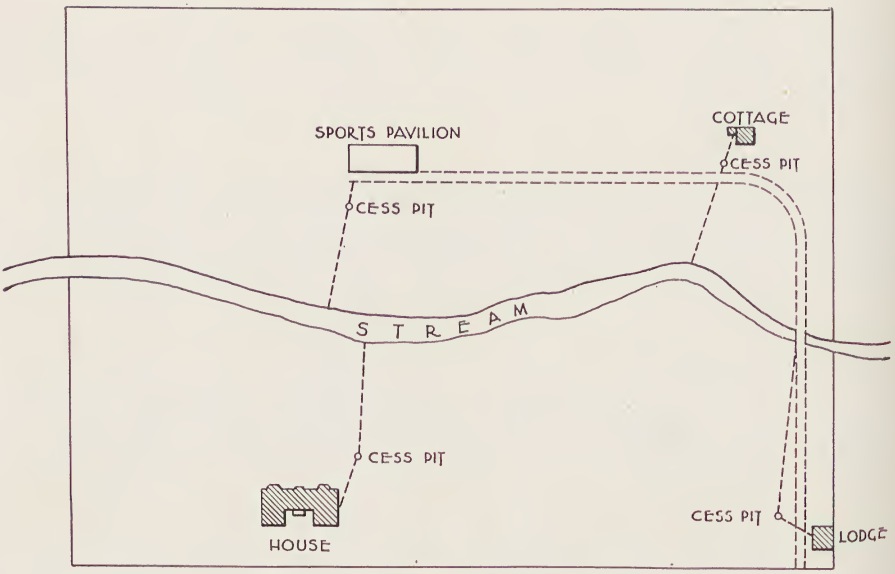


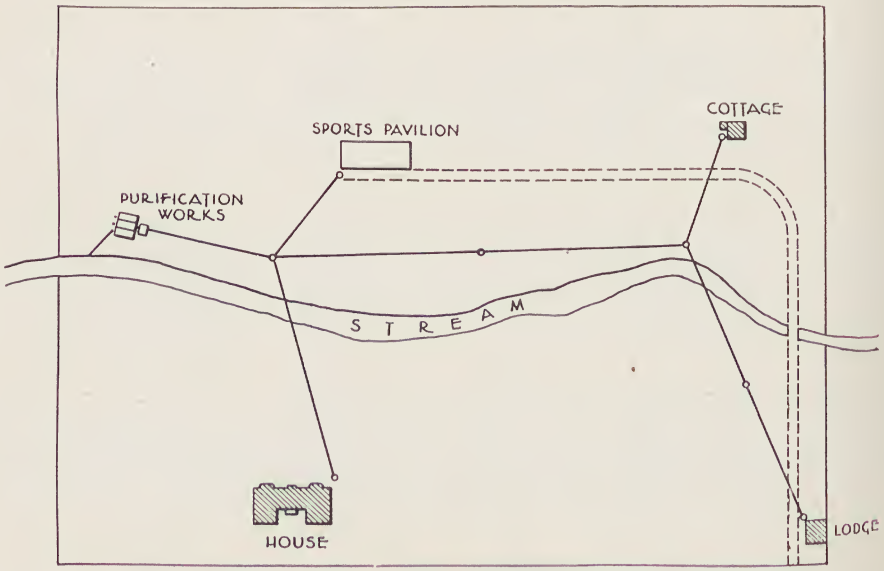
Fig. 15.—SEWAGE DISPOSAL—TWO METHODS COMPARED

In case A, sewage is pumped by hand on to the ground, where it soaks away in trenches, causing aerial nuisance and unsightliness. In case B, liquid sewage overflows into sub-irrigation drains, pumping is avoided, and there is no nuisance.



BAD ARRANGEMENT

Fig. 16.—THE DISCHARGE FROM VARIOUS BUILDINGS ON A SMALL ESTATE MAY CAUSE GREAT NUISANCE AND STREAM POLLUTION



GOOD ARRANGEMENT

Fig. 17.—ALL CESS-POOLS, ETC., REMOVED AND BUILDINGS DRAINED TO SMALL SEWAGE PURIFICATION WORKS

normal conditions. Conditions vary greatly, and the adoption of a process which has given good results at one place may either involve unnecessary expense or may prove to be insufficient at another. Speaking generally, however, a tank or tanks are arranged so that the liquid sewage may be discharged on to the filters in as fresh a condition as possible, and the solids are intercepted and digested. The filter generally consists of clinker or other suitable material. Sometimes the sewage is made to pass through two filters in succession.

For very small installations, the sewage is generally distributed in troughs through which it trickles on to the filter (Fig. 18), but there are other devices whereby the sewage is sprayed in jets.

For larger filters rotary sprinklers are used, but these require more attention (Fig. 19).

Where it is possible to distribute the filter effluent over porous land, it is sometimes possible to omit a part of the purification works. It should be noted that filtration through land is excellent final treatment. Where the sewage has to be pumped, it is sometimes advantageous to pump the effluent after treatment, and there is a possibility of utilising a windmill for such pumping, although provision must be made in such cases against the time when the wind fails (Fig. 20).

In relation to farms, it will generally be found that great wastage of farmyard manure occurs. It is apt to remain about in the farmyard, the drainage from which frequently runs to a pond and pollutes the water from which cattle drink. By a better arrangement of drains such material may be carried to a tank. Straw filters are effective for the purification of sewage, and it should be possible by the use of straw and the farmyard drainage to produce manure which is badly required.

In draining a number of isolated school buildings situated on a large estate, a number of catch-pits was discovered on the course of the main drain. Such pits as these are very objectionable, and if they are found to exist they should be removed. A very large quantity of rain-water entered this system. Purification works, including a filter with a rotary sprinkler, were installed, and an arrangement was made whereby the rain-water overflowed from the sewers directly into the river when the rate of flow exceeded six times that which would occur in dry weather. Thus all foul sewage was purified on works of moderate size, and the storm water which did not require purification was discharged separately.

FACTORIES

Sanitary Accommodation

In the drainage of factories many problems arise which are of a different nature from those encountered elsewhere. A factory is a commercial undertaking in which efficiency and the saving of the workers' time are all-important.

If, for example, 370 persons employed in a factory waste on an average

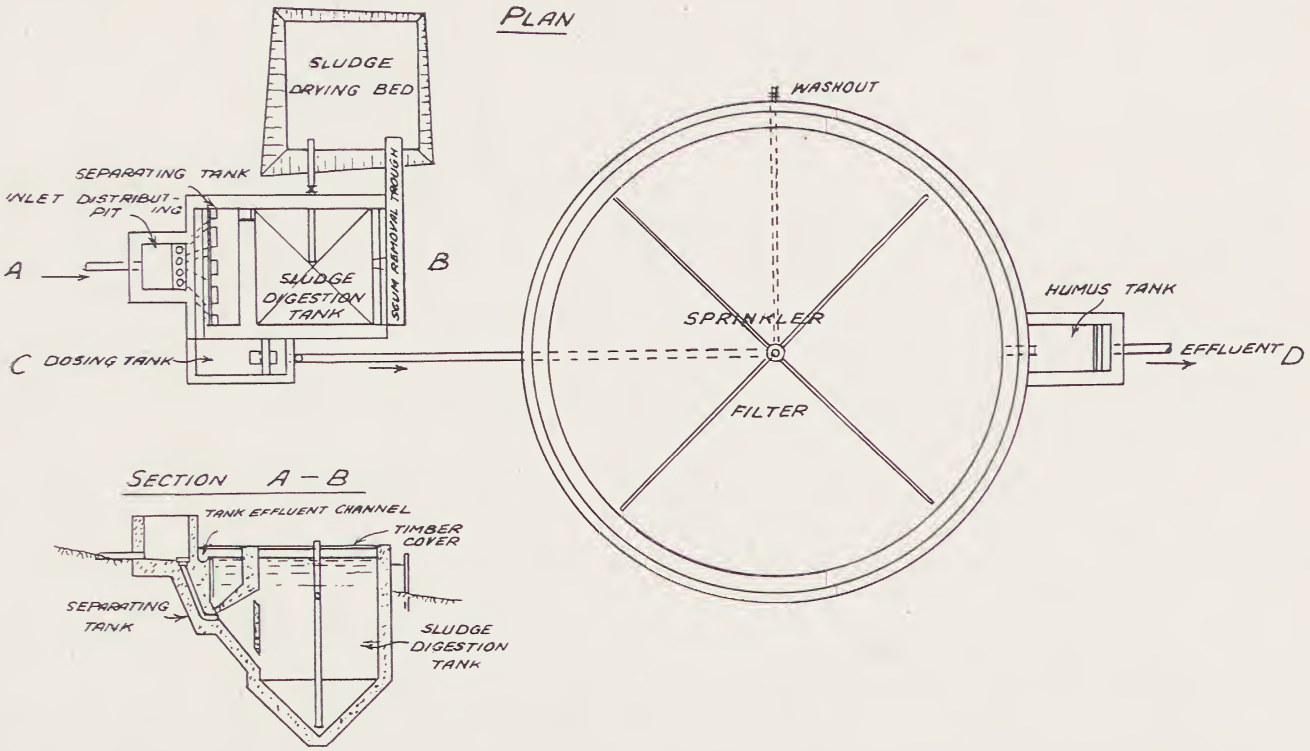


Fig. 19.—NORMAL SYSTEM OF SEWAGE TREATMENT FOR LARGE HOUSE, INSTITUTION, OR SMALL ESTATE

The solids are separated from the sewage and are digested in a separate tank. The fresh liquid sewage is delivered in small doses on to a revolving sprinkler filter. Section of sprinkler filter is shown in Fig. 19A.

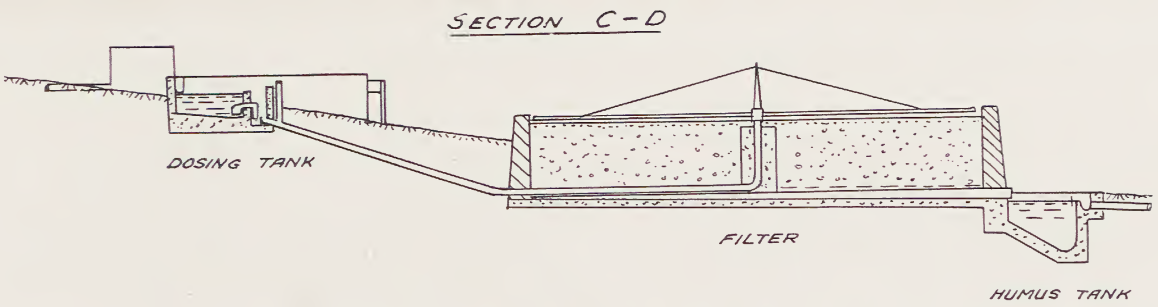


Fig. 19A.—SECTION THROUGH REVOLVING SPRINKLER FILTER (SEE ALSO FIG. 19)

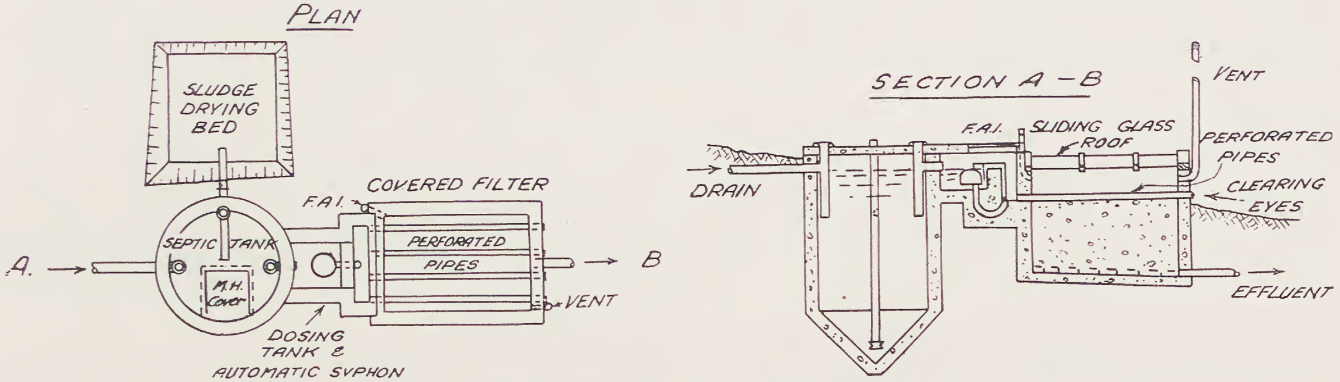


Fig. 18.—NORMAL SYSTEM OF SEWAGE TREATMENT FOR SMALL HOUSE

Equipment consists of septic tank, dosing tank, and fixed sprinklers over covered filter.

only one minute per head per day, owing to insufficient or inconvenient sanitary accommodation, it is evident that a total loss of 6·16 hours per day will be incurred, which, priced at 1*s.* 3*d.* per hour, would equal 7·70*s.* per day, or about £116 per annum. This sum would represent the interest on £2,320 capital invested at 5 per cent. interest.

It is therefore evident that if such waste of time can be avoided by a better provision and arrangement of sanitary fittings, the matter is worthy of serious attention.

The psychological effect of good sanitation is also admitted to be very important. Good fittings, fixed in well-ventilated and well-lighted places, with walls, floors, and partitions capable of being easily cleaned and not easily damaged, will be maintained in good condition with ease, will not be so likely to be misused or broken, and can be easily inspected.

While, therefore, it is possible to install the minimum amount of sanitary accommodation to comply with the demands of the Factory and Workshops Act, which is thirty-seven years old, and which does not represent the requirements of the best modern practice, or the most economical provision of sanitary fittings under present conditions, it is, speaking generally, false economy to adopt the minimum.

Position of Sanitary Accommodation

In relation to the position of the sanitary blocks, centralisation is certainly advisable. The point is, however, one of considerable economic importance and the fact that workmen and members of the clerical staff may have to walk considerable distances, perhaps 300 or 400 yards, in order to reach a sanitary block and to return to their work, will suggest that such distances should be shortened. The installation of sanitary fittings, each set being arranged at or near a place where a group of workers will be constantly employed, is always worthy of consideration.

Against this arrangement may be set the fact that centralisation makes effective supervision possible, and that without such supervision some workmen may deliberately waste time in the sanitary blocks.

Closet Accommodation Required

The closet accommodation required under the Public Health Act and the Factory and Worskhops Act is as follows :—

For women workers there must be one water-closet for every twenty-five persons.

For workmen there must be provision of one water-closet for every twenty-five for the first hundred, and one for every forty afterwards, provided that there is sufficient urinal accommodation.

Since the War certain orders have also been made by the Home Office under the Factory Act whereby washing accommodation may be demanded if the conditions are such as to require it for health and safety. A factory drainage scheme must also conform to the by-laws of the local

authority. It does not appear that the Factory Act makes any special requirements in relation to the clerical staff.

The actual minimum of sanitary accommodation required in order to avoid legal action should not be the basis upon which an intelligent factory authority or their engineer should work. It is obvious that an average allowance of, say, one water-closet for thirty-four men—as would be required by the Act for a factory of 370 men—would be likely to lead to inconvenience and waste of time if these men worked for ordinary hours, and that the arrangement would not be economical. The provision of a few extra water-closets in a range is not a costly matter in relation to the value of the work.

In the writer's opinion the provision of one water-closet for twelve persons would not be extravagant in the case of a factory of moderate size.

Washing Facilities Required

The provision of suitable washing-troughs for workmen and lavatory basins for the staff should be in accordance with good modern practice. It is also obvious that the urinal accommodation should not be limited unduly. It is advisable and in agreement with ordinary practice that one or more of the water-closets should be reserved for the foremen.

There are three main possibilities with regard to washing facilities. A range of basins, long washing-troughs, and circular washing-troughs. The circular washing-troughs possess the advantage that while they occupy the minimum amount of space they can be fixed easily, and do away with a certain amount of plumbing work. They are also economical in the use of water. Such troughs have been installed at various works of importance ; they are, however, more costly than long washing-troughs. A range of lavatory basins would be more expensive than troughs, owing to the amount of plumbing work required and to the cost of fixing. They are also more likely to be injured than are the washing-troughs.

In considering the number of sanitary fittings required for the clerical staff it should be remembered that discontent and waste of time may be more important in the case of highly paid assistants, and are possibly more likely to occur, than in the case of workmen ; for such reasons ample and well-arranged accommodation is very desirable.

Sanitary Fittings for Factory Use

Fittings for factory use should be of strong construction. For this reason the cheaper forms of earthenware are unsuitable. Hitherto, when rough usage was probable, fittings made of fire-clay have been used, but recently a strong, vitrified glazed ware, known as vitreous china, which has long been in universal demand in America, has been introduced.

In a factory it is generally undesirable to have anything in the nature of a hinged water-closet seat, because such seats are apt to be misused

and are frequently found to be broken away from the hinges or loose. A better plan is to provide water-closets of the type in which no wooden seat is required because wooden pads are fixed in the basin itself.

There are other and older forms of water-closet which were formerly used in factories, such as a long, open trough running under the seats, flushed periodically by means of an automatic tank. This appliance has many objectionable features, and is no longer used in good practice. Similarly, the isolated pedestal latrine arrangement on much the same principle, but with a pipe instead of a trough, is no longer used. In general practice it has been found best to provide a strong type of water-closet without any movable woodwork, flushed by means of an ordinary water-waste preventer. A rod or encased chain should be provided in place of the chain used for domestic appliances. For the staff lavatories, ordinary water-closets, as provided for domestic use, are suitable.

Urinals for Factories

With regard to urinals it is undoubtedly desirable that they should be made of white glazed fire-clay, suitable for cleaning at all points. If any other course is adopted, it is extremely difficult to ensure that they will be kept clean and in proper order. On the other hand, such fittings are relatively expensive. Urinals can be constructed of slate, enamelled slate, glazed ware, or painted cast iron. They are sometimes formed with plain cemented backs. Such types, however, are not to be recommended, owing to the difficulty of keeping them in order, and to the probability of an insanitary condition arising. It is also doubtful whether a good local authority would approve of them, glazed ware being demanded in many of the by-laws.

Rain- and Surface-water Drainage

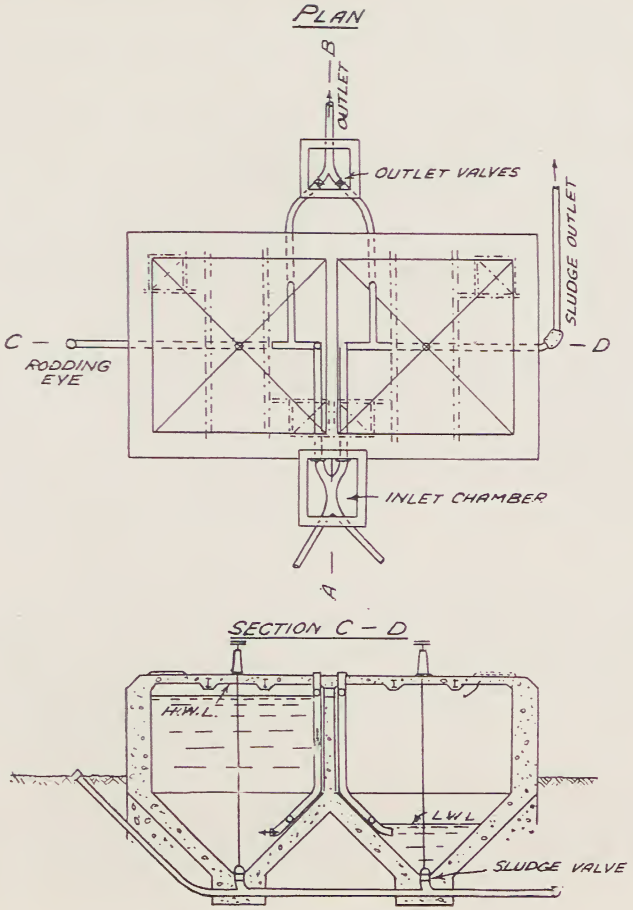
The drainage of rain-water from roofs and surface water from yards may often prove to be a matter of importance and difficulty. Flooding of the ground must be prevented, and the large volume of this drainage may be such that the local sewer cannot carry it. Each case needs special consideration, but the matter should not be overlooked when a scheme of factory drainage is planned.

SCHOOLS AND INSTITUTIONS

Schools

In the drainage of schools particular attention must be given to the provision of a proper number of sanitary fittings of all kinds. The number of closets, baths, lavatory basins, and sinks, and possibly of laundry appliances, must be considered in the light of common sense, and experienced medical opinion should also be obtained.

In the text-books certain allowances for water-closet accommodation are given. Such figures, which are generally based on the Factory Act



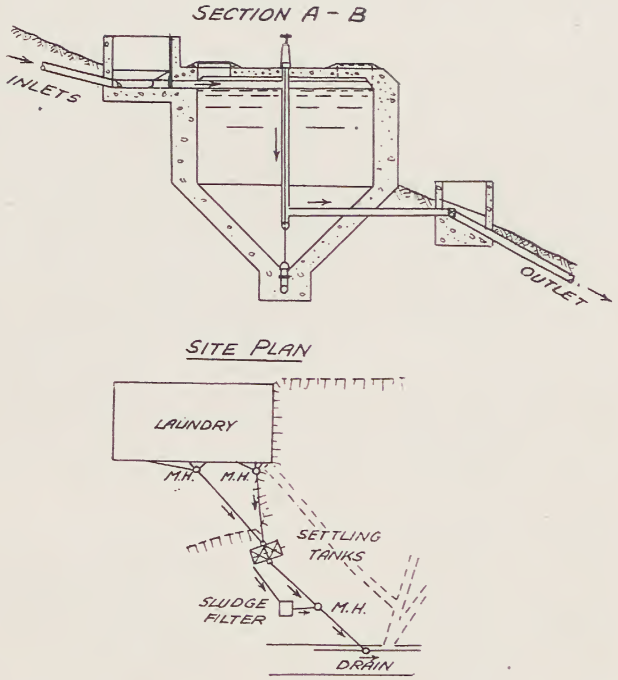


Fig. 21.—Laundry waste tanks

Waste flows into one of the tanks and is held for twenty-four hours before being discharged into drains. Sludge and scum remaining in the tank are treated on screening filter, liquid from which runs to drain. One tank stands full for settlement while other tank is filling.

allowances, should be regarded with great care. The requirements of a county council school attended only by day scholars cannot be taken as a basis for a school where the scholars and teachers are resident. The requirements must necessarily differ in each case. For reasons of convenience and for reasons of health, it is desirable that ample provision should be made, and the cutting down of the allowance to a minimum should be strongly opposed. The same applies to hotels, institutions, hospitals, and asylums.

Hospitals and Asylums

In hospitals and in asylums special provision of sanitary fittings must be made in accordance with requirements, which will vary in each case. This provision will generally have to include special laundry facilities, and the drainage from the laundry and possibly from a disinfecting station may introduce special problems.

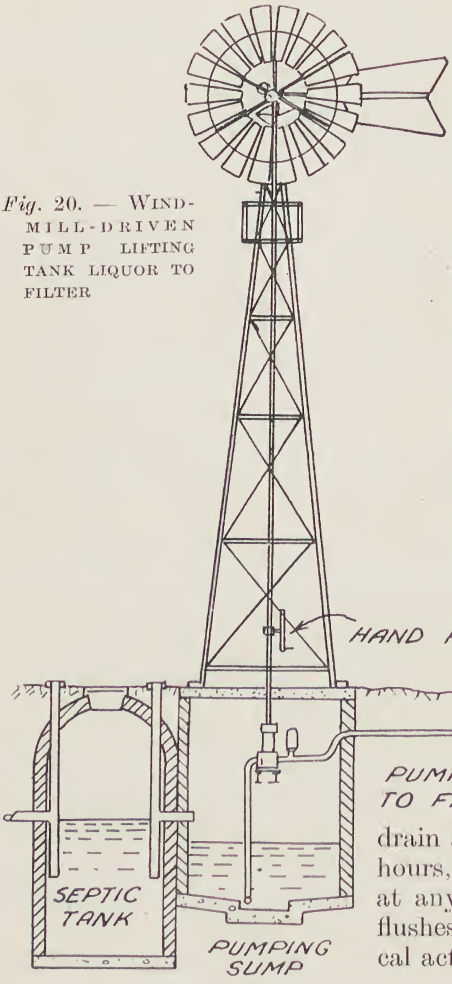


Fig. 20. — WIND-MILL-DRIVEN PUMP LIFTING TANK LIQUOR TO FILTER

It should be noted that the discharge of laundry waste and disinfectants into the drains may affect the quality of the sewage adversely, so as to interfere with the biological action of the purification works. One method of dealing with such wastes is to provide separate tanks, each holding a day's flow of the laundry waste, from which only the liquid is decanted into the main drain after twenty-four hours' settlement (Fig. 21). The sludge and the scum are intercepted in the tanks and are treated separately—generally in a small straining filter from which the liquid runs to the main drain. The liquid decanted from the tanks is allowed to flow into the main drain at a slow rate over the twenty-four hours, so that the admixture with the sewage at any time is slight, and so that sudden flushes, which are likely to upset the biological action in tanks or filters, may not occur.

STRONG ROOMS AND SAFE DEPOSITS

By H. Guy Holt, F.R.I.B.A., M.I.Struct.E.
(*Consulting Architect to the Bank of British West Africa, Ltd.*)

STRONG rooms and safes of varying degrees of security are provided for banks, insurance and building societies' offices, general office buildings, stores, safe deposits, jewellers, pawnbrokers, and diamond and precious-stone merchants.

In the case of the last three it is usual to provide safes, but owing to the number of cases in which thieves have made off with a complete safe, to break open at leisure, the tendency is for a small strong room to be built for additional security.

For Office Buildings

With regard to ordinary office buildings, it is usually sufficient to provide a room which is fire-resisting and water-resisting. In the case of strong rooms of this type erected in the basements of very high buildings, the construction should be shockproof also.

Banks

Banks, however, require a much greater degree of security, but here again the degree of security depends entirely on the type of bank and its business and the locality.

A much greater degree of security is required in the strong rooms of the head office of an important bank, where large sums in bullion and notes, bearer bonds, etc., may be kept, than in a small country branch. Again, the large central banks in most countries are to-day built to withstand not only expert burglary, but attack by possible revolutionists and rioters.

In the ordinary way it is considered sufficient if "time security" is afforded to give protection over a week-end from Saturday noon to Monday morning, although in this country any important bank branch would or should have protection from Saturday noon to Wednesday morning, this being the longest period of Bank Holiday should Christmas Day fall on a Monday.

In large banks three or four strong rooms may be required for various purposes and of differing degrees of security: they may be (1) book

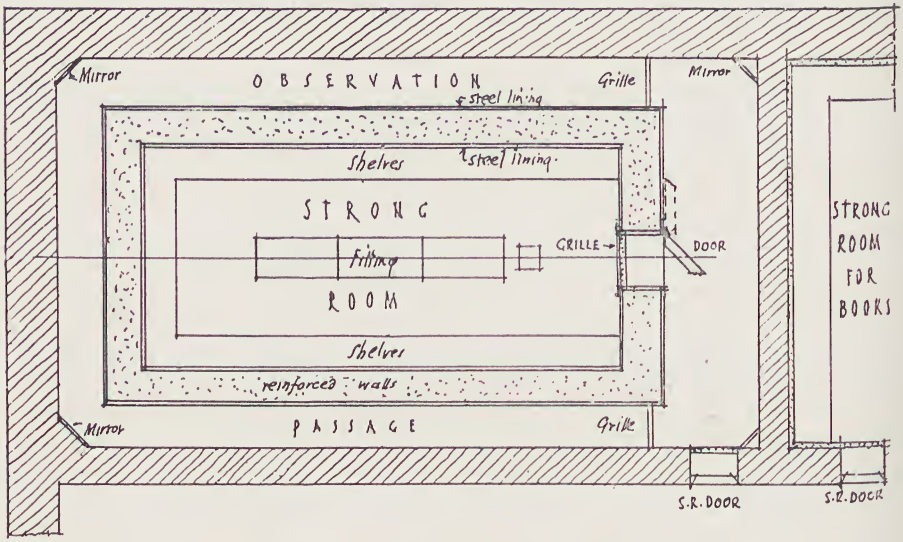


Fig. 1.—STRONG ROOM WITH OBSERVATION PASSAGE

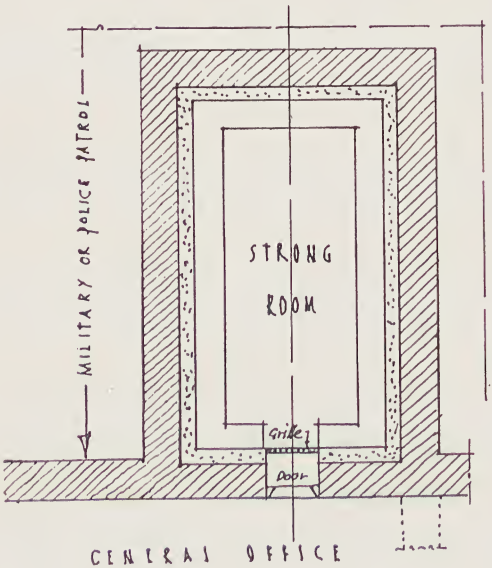


Fig. 2.—STRONG ROOM ON EXTERNAL WALL

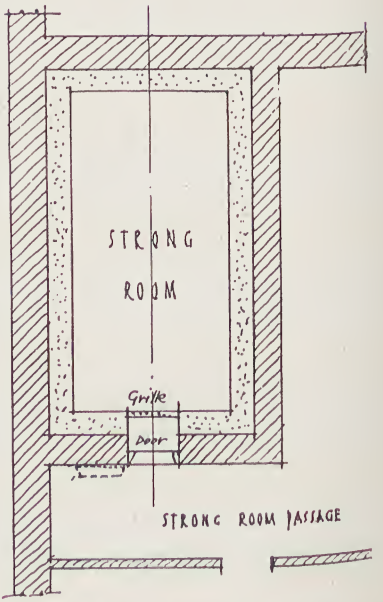


Fig. 3.—BRANCH BANK STRONG ROOM IN ANGLE

rooms, (2) voucher-filing rooms, (3) document rooms, (4) treasury or bullion rooms.

The time-factor degree of security to be given will be decided with the client, but the manner of effecting it will probably not be arrived at until a number of consultations with one or more of the leading bankers' engineers have taken place, and possibly special tests have been made on different forms of construction.

The bankers' engineer can be relied on to give a fair estimate of the time value of various forms of security without giving actual guarantees, the best class of English engineer being especially reliable in this respect.

The war between the expert safe maker and strong-room constructor and the expert burglar is ever being waged—fiercely, if silently—and only when a sensational coup is brought off do the general public realise that this war is going on around them all the time. The necessity for the adequate protection of valuable documents and important correspondence from loss by fire, water, and collapse is being realised by all important business concerns to a much greater degree than heretofore, as the consequential loss in business after a fire, although an insurable risk as a rule, is often not a paying proposition. For this reason strong rooms are constantly being built in connection with the offices of important institutions, and the steel filing cabinet, inside a properly designed strong room, meets the case from the point of view of security, space saving, and economy of clerks' time.

DESIGN

With these preliminary remarks we can turn to the question of design and construction.

Usually strong rooms and vaults are placed in basements or sub-basements, as being more economical in floor space, and giving privacy for staff in the use of the strong rooms, with less liability of raid or gang attack during office hours ; safety and economy in construction are also usually effected by this disposition.

This is not always the case, however, and in small branch banks in this country it is quite common to find the strong room on the ground floor at the rear of the premises.

Where strong rooms are desired on upper floors it is necessary that the steelwork supporting the same in high buildings be much more fully protected against fire and water than would otherwise be the case. In the majority of cases upper-floor strong rooms are undesirable unless built one over the other as a separate structure, independent of the remainder of the building.

Isolation

It is good practice to isolate the strong room so that it forms an " island " with access from the lobby to the door and an observation

passage all round sufficiently wide to see down, but not wide enough for a burglar to work in.

Thus the ordinary walls of the building must be broken through before an attack on the strong room itself can take place.

In some banks a patrol corridor is provided instead of an observation passage.

It is economical to place the door of the strong room on the narrow end where possible, and this also gives better access and supervision since it is often the practice to leave open the outer door, during office hours, merely keeping locked an inner grille door. This ensures some ventilation of the strong room during the day.

The minimum width of any strong room of sufficient importance to be considered in this article should be 6 ft.

This allows of a door about 3 ft. wide and shelving 18 in. wide down either side, with a 3-ft. passage between. A great deal more than this is, of course, often provided according to requirements; in fact, the writer has designed strong rooms of all sizes up to 20 ft. wide and 70 ft. long, to take over £2,000,000 worth of notes in addition to specie.

Very often the space available for strong rooms in a small bank is limited, and where more than one purpose is to be served this can often be achieved by fixing across the room a strong steel grille the full height of the room, having a strong gate with suitable locks. The inner portion then serves as a treasury, whilst the outer part can be used for books, etc.

The height of strong rooms is often limited by the height of the basement storey, but it should never be less than 7 ft., and of course more than this is desirable and often necessary.

Ventilation

Air is fairly stagnant in strong rooms, and a certain amount of cubic space beyond merely economic requirements is desirable. This is especially the case where manager and clerks may have to spend considerable time examining documents, counting specie, etc., inside the room.

Special ventilation of strong rooms is necessary for the purpose of drying out during finishing and for ordinary use of the room. In some cases special cranked flues are built into the walls, the opening of which is fitted with a steel weight or ball, released by a fusible link in case of fire so as to close the ventilator automatically.

Special burglar-, fire-, water-, and explosion-resisting ventilating ducts are designed to be incorporated in large strong rooms at suitable points.

CONSTRUCTION

Simple strong rooms may be built of blue brick in cement with mass-concrete floors and a steel and concrete roof, but such are in no way burglar-resisting.

The walls, floor, and ceiling or roof of the strong room should all be of equal relative strength from the resistance point of view, and I think it is sometimes overlooked that the floor of the strong room is often its most vulnerable point, as tunnelling has often been resorted to by bank cracksmen working from adjoining buildings.

Many forms of wall, floor, and roof have been devised, generally of some form of steel and concrete construction ; these and the question of doors, etc., are dealt with below.

Position of Room

The position of strong rooms in the basement of buildings, which I have advocated above and which is usual, has sometimes been criticised on account of the fact that water damage has occurred in various cases, particularly after fire. The water from hoses has done serious damage to papers and important documents. Despite this, under normal conditions the basement is the proper place for the strong room.

Economy in valuable ground-floor space, privacy, and less liability to raids by gangsters and rioters are some of the main considerations. Great economy and safety in construction are thereby secured in addition. To carry the tremendous loads accruing from the solid construction of a modern first-class strong room with its contents, not to mention the door, often weighing several tons, from the ground-floor level to a basement, or sub-basement, would necessitate extremely heavy and costly steelwork or reinforced-concrete construction. That is, of course, if a basement be intended to cover the whole of a site : such is usually the case in buildings for the head offices of banks and insurance companies in large cities, which are the cases I have in mind. I have previously stated that in small branch banks, etc., the strong rooms are often placed on the ground floor, and where no basement exists there are good reasons for it. It has also been argued that the transfer of books, specie, and bullion from upper floors to the basement is a source of annoyance and waste of time. Such is true up to a point. In these days of electric bullion and book lifts, however, there is very little to choose between the ground floor and basement floors. Security is of greater importance than the mere fact of saving a few minutes' time on the part of messengers and other staff.

It is, of course, essential that the strong room and its surroundings must be adequately protected not only from fire, burglars, rioters, and gangsters, but from water damage as well. Whether such water damage be from hose pipes in case of fire, hydrants, sprinklers, or other fire-fighting devices, backing up of sewers in low-lying sites, flood water, tidal wave, springs, or underground rivers, the strong room and all approaches thereto must be guarded. The proper waterproofing of the basement floors and walls from extreme external water pressure is definitely part of the architect's job in the ordinary way ; much will depend on the type of site.

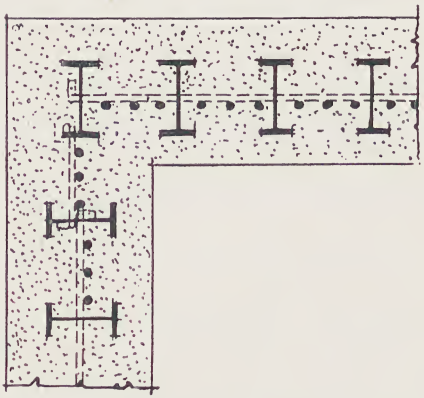


Fig. 4.—PLAN OF WALL CONSTRUCTION WITH R.S.J.S AND ROUND BARS

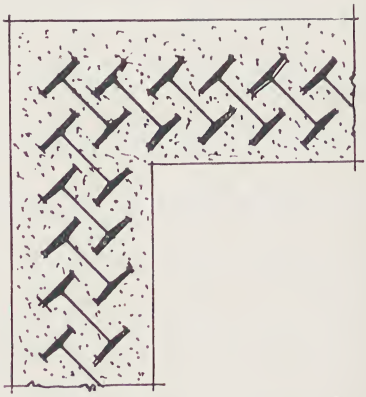


Fig. 5.—PLAN OF WALL CONSTRUCTION WITH DIAGONAL R.S.J.S

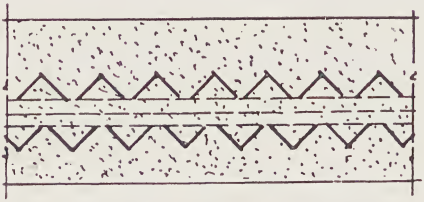


Fig. 6.—PLAN: WALL WITH ROLLED-STEEL ANGLES

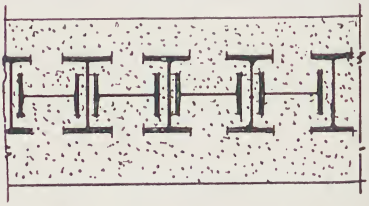


Fig. 8.—PLAN: WALL WITH R.S.J.S CROSSED

Fig. 7.—WALL WITH VARIOUS R.S.J. COMBINATIONS

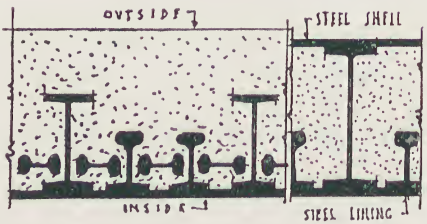


Fig. 10.—WALLS WITH R.S.J.S AND BULB TEES AND BULB BARS

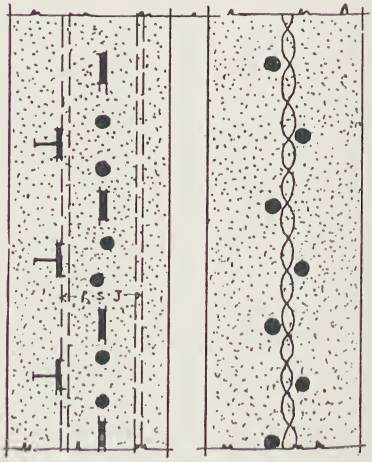


Fig. 9.—SECTION: WALL WITH R.S.J.S, FLATS, TEES, AND ROUNDS

Fig. 11.—WALL WITH TWISTED STEEL BARS AND ROUNDS

In cases where a new strong room is to be erected inside an existing building it is very necessary to make full inquiries as to this waterproofing, and to take all necessary precautions to avoid possible complications under this head before commencing operations.

The plans shown in Figs. 1, 2, and 3 demonstrate various positions for strong rooms. Fig. 1 shows the usual position of a strong room in the basement of a large bank head office, with the observation passage around it. Fig. 3 shows a typical position for a ground-floor strong room in a small branch bank. Fig. 2 shows an unusual position on the ground floor of a small branch bank in the Colonies, where police or military guard was constantly provided by the Government. Here, outside observation is afforded by the guard, and also by European staff housed on the first floor of the building. Each case must be dealt with on its own merits, and it is impossible to legislate for all cases without a thorough knowledge of the local conditions and particular requirements of each case.

Position having been carefully considered, and the most desirable place for the strong room having been ascertained, the position and size of the door, its quality, and the general degree of security for the whole job settled, we now come to the question of the construction of the strong room itself. Walls, floor, and roof must be of equal strength from the security point of view.

Wall Construction

The writer believes in a self-supporting type of construction for the strong room where possible (i.e. a framework of steel for walls, floor, and roof, tied in at the angles and capable of standing alone as a unit steel structure). This gives greater strength, security, and rigidity in case of shock due to earthquake or collapse of upper floors in the building in fires, whether the room be steel-lined or not.

Simple forms of construction may next be inquired into, and Fig. 4 shows a combination of ordinary rolled-steel joists as uprights in the walls and as floor joists and roof joists, with 1-in. or over diameter steel rods, flats, or bars threaded through same at close intervals, there being not more than 2 in. in the whole arrangement which is not covered by one or other of the steel members. The whole is concreted in carefully, great care being taken to fill all voids. The best aggregate to use is undoubtedly fine granite chippings from Shap Fell or other well-known quarry. Failing granite, hard York stone, with a certain small admixture of broken blue brick, is admissible. Usually the aggregate is small; firstly, to fill in between the steel members, and secondly, to make it impossible to remove large lumps of aggregate at one time by creating large holes in the concrete for the insertion of explosives, etc. Another form of construction is shown in Fig. 5, where rolled-steel joists are placed diagonally in the concrete, the idea again being to make things more difficult for the burglar, and to puzzle him as

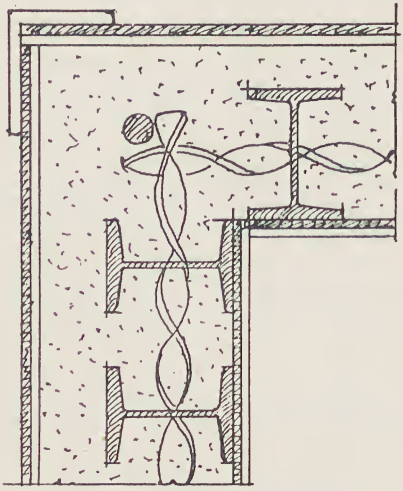


Fig. 12.—STRONG-ROOM WALL CONSTRUCTION OF ROLLED-STEEL JOISTS AND TWISTED STEEL BARS

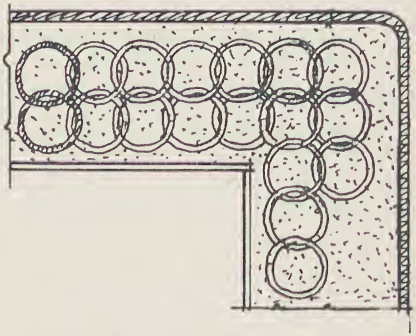


Fig. 14.—INTERLOCKING SPIRAL REINFORCEMENT FOR STRONG-ROOM CONSTRUCTION

Fig. 13.—INTERLOCKING "TANGBAR" REINFORCEMENT

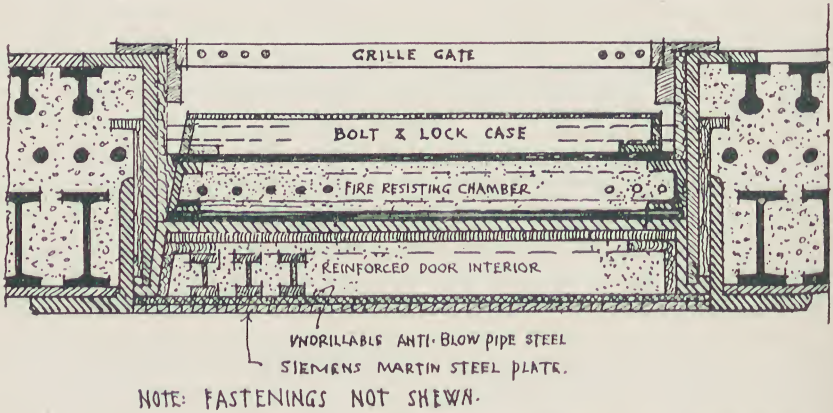


Fig. 15.—DIAGRAM SHOWING APPROXIMATE CONSTRUCTION OF A TREASURY STRONG-ROOM DOOR, "GRIP" FRAME, AND GRILLE GATE

to the whereabouts of the steel reinforcement and at the same time cause him as much trouble as possible in drilling into the wall by making his drill continuously slip off the surface of the steel. Another variation of this arrangement is shown in Fig. 6, where steel angles are combined in a somewhat similar fashion.

Various combinations will occur to architects, and heterogeneous collections of rolled-steel joists are shown in Figs. 7 and 8. In Fig. 9 rolled-steel joists have their webs punched at intervals, and steel flats and round bars are threaded through them, with steel tees alternating in position on either side of the joists. A stronger form is shown in Fig. 10, in which the steel joists are combined with bulb tees and bulb bars. There are different patented systems of construction which have been brought out at various times by some of the well-known security engineers. Amongst these I would refer to the twisted-steel-bar system combined with rods as shown in Fig. 11, and with steel joists as shown in Fig. 12. These twisted bars are of hard-tempered steel which is drill-proof and sawproof. A further type is that consisting of a central rod having numerous steel fangs projecting in all directions around it. These bars are placed closely together in the walls, floor, and roof of the room, just affording sufficient space for the small-aggregate concrete to pass through, and completely cover all steel and avoid holing. See Fig. 13.

While on the subject of concrete I would point out that whilst a small pea-sized aggregate of a hard substance such as granite chippings is required, and the steel must be placed as closely together as possible, the consistency of the concrete and water content should be carefully watched to see that it is not too wet, or in too liquid a state when placed in the forms, otherwise the concrete will not be of the strength expected.

Another form of construction, differing essentially from the foregoing, is that by another well-known firm of bankers' engineers, and consists of a spiral steel reinforcement, made up of $\frac{1}{2}$-in. steel bars, forming spiral coils 5 in. in diameter, with a vertical pitch of $3\frac{1}{2}$ in. In addition, rods are threaded through the coils, the bars of which are interwoven to form a complete mattress of steel (see Fig. 14). A further form of construction is that of precast-concrete blocks, reinforced with rods, which has been patented by a well-known firm. In this case the blocks are specially cast at their works and thoroughly dried and matured, and may be used on strong-room work where the need is very urgent.

The writer has used nearly all the above forms of construction in various strong rooms of differing degrees of security. None of them is perfect, and each type has its own advantages and disadvantages, which it would be, perhaps, invidious to discuss further here.

Steel Wall Lining

A further protection to the strong room which we have not yet discussed is the lining of the room with steel, either inside or outside, or

both. The last is costly and affords much greater protection, and will usually be used only on the best type of room.

It is a well-known fact that the thermal conductivity of concrete is comparatively small, and for that reason good-class concrete is one of the best fire-resisting materials we have. Further, it is practically proof against the oxy-acetylene blow-pipe and is therefore used largely in strong-room construction. It is, however, very subject to shock, and although the best type of small-aggregate granite concrete is difficult to pierce, it is quite possible to drill a hole of sufficient size to insert an explosive. For this reason it is necessary in the best work to use a non-drillable steel lining on the outside of the walls. The thickness of the walls may vary from 18 in. to several feet, according to requirements, and in the usual run of rooms is from 18 in. to 2 ft. 6 in. It will be seen, then, that a very good type of room can be built by building a central core of concrete with one or other of the reinforcements mentioned, or other combination of same, with special steel-plate covers outside and inside the room.

In the simplest forms of room these plates are of Siemens-Martin steel, the joints of the plates being machined to great accuracy to ensure extremely tight fitting, and the plates are riveted to rolled-steel joists or other reinforcement with countersunk rivets. It is thus possible for the plating on one side to act as shuttering for the filling in of the concrete. In better-class strong rooms, where great security and strength are required, and sometimes space-saving as well, the steel plates are of special drillproof and anti-blow-pipe steel, thus affording a still further degree of security.

In case extraordinary security is required it is, of course, possible to construct a room within a room ; this means forming an outer shell of reinforced walling with special reinforcement between steel plates on both sides, and again a further wall of similar construction inside the first. This gives great thickness and strength, and also has a psychological effect on the skilled burglar who, after hours and hours of effort with drills, saws, blow-pipe, and explosives on the outer shell, may eventually penetrate a small portion only to find that he has to start all over again with another unknown proposition, which may be worse than the first, from his point of view.

With regard to the value of different forms of reinforcement there is general agreement, I think, that the closer type of irregular reinforcing steel is best. Many tests have been made by the various specialist firms dealing with strong-room construction, and it is usual for architects, bankers, and others interested for particular reasons to see one or more of these tests carried out on the particular type which they think of adopting. Tests on strong-room walling constructed with rolled-steel-joist reinforcement, revealed that it is comparatively easy to obtain a seating in the wall of concrete by means of " Ingersoll-Rand " or other

drills for insertion of an explosive, as the steel was not sufficient in quantity or close in spacing to afford interruption. After the explosive had been fired, the wall collapsed. In the case of lighter but closer-spaced special reinforcements, the tests showed that it took much longer to obtain sufficient seating in the concrete for the insertion of the explosive, and after firing the concrete was not shattered but a hole was blown through the wall of only small diameter.

Floors and Roofs

The construction of floors and roofs will naturally follow very closely that of the walls, as the type of reinforcement considered suitable for the latter will suffice for these. The roof must be considered from the point of view of possible shock of falling material, and in some cases bombs, and the floor should be protected from attack by excavation below, and also from water damage, however arising.

Doors and Frames

The old type of angle-iron door frame is obsolete, and frames should be of the " grip " type as shown by the sketch in Fig. 15. These can be built in as the work proceeds, and the doors and grille can be hung later. This procedure is advisable on account of the fact that if doors are hung at first, some months may elapse before the strong room is thoroughly dried out, or required for use, and in the meanwhile the interior of the door, locks, etc., have been damaged by rusting up.

Speaking generally, the door and frame must be equal in resistance to the walls, or *vice v rsa*. They should be proof against all mechanical attacks by means of hammer, chisel, electric or pneumatic drill, oxy-acetylene blow-pipe, and various types of explosives, of which gelignite is the commonest used. The manner in which this is to be most efficiently and cheaply achieved is the business of the security engineer, but the architect responsible for the whole work will inquire very closely into the various types of protection put forward. Most doors consist of a series of steel plates of various combinations.

It is against a combined form of attack that the maker has to guard. One of the best forms of blow-pipe resistance consists of a copper plate, the reason for this being that copper is one of the best known conductors of heat, apart from various precious metals. This peculiarity causes heat applied to the surface of a plate of copper to be dissipated very quickly over its whole area ; so rapidly, in fact, that there is no time for any heat concentration at the point of application of the blow-pipe. It was at one time thought that quite a thin sheet of copper would suffice, but this is not the case. A thin sheet of copper will dissipate the heat from an oxy-acetylene blow-pipe for a very short time without apparent damage, but to achieve permanent immunity the copper should be not less than $\frac{1}{4}$ in. thick. A copper plate over $\frac{1}{4}$ in. thick, of the usual area

of a strong-room door, i.e. about 6 ft. 6 in. by 3 ft. 6 in., is absolutely impenetrable by the oxy-acetylene blow-pipe. Of course it is easily pierced by other means, and therefore the copper plate is protected by tough steel, drillproof, and other types of steel cover, front and back. There are, however, a few steel alloys of comparatively recent discovery which are not only sufficiently hard to resist drilling of any known kind, but are also absolutely blow-pipe-resisting to the highest degree for all practical purposes. It must not be forgotten that to apply oxy-acetylene blow-pipe, large cylinders of oxygen are required. For each 100 cu. ft. of gas a cylinder weighing 1 cwt. is required, in addition to tubing and other apparatus.

There is a distinct limit to what skilled burglars are able to cart about without notice by police, watchmen, etc., although they have been known to boldly draw up to premises which they intended to burgle, with all their bulky and heavy apparatus in a pantechnicon. The door, then, usually consists of a large outer shell made up of a number of plates of hard-tempered and drillproof steel, with a plate of copper or other anti-blow-pipe metal, a hollow chamber in which the bolts are situated, and again, on the inner face, further plates and generally a chamber filled with fire-resisting composition generating moisture, as an added protection in case of fire. On account of the thickness necessary to accommodate these components, it is necessary to splay the opening edges of the door for opening purposes. The closing stile of the door is arranged to fit very tightly to the frame, and in good practice is rebated and grooved into the frame jamb in such a way as to prevent the insertion of explosives. A kind of tongue-and-grove joint is thus made with a liquid-tight packing.

In many cases the thickness of the door required is so great that ordinary hinging becomes impossible, and a projecting hinge, known as a crane hinge, is used. By this means the door opens at first with a movement parallel to the jamb of the frame until it is free sufficiently to open in the ordinary way. The interlock of door and frame also prevents the insertion of wedges or jemmies to loosen the door sufficiently for the insertion of explosives.

The strongest form of door, and one rarely used except for extreme security, is the circular strong-room door ; this type was first brought out in America, but is made by all the leading English engineers. The doors may weigh up to 4 or 5 tons each, yet are made so beautifully and balanced that they may, when unlocked, be opened and pushed back by the little finger. In fact, the whole of the work of a first-class English security engineering firm is so thoroughly high-class and well finished that the fine adjustments and quality of work are exceptional even in this country.

INTERNAL WALL TILING

GLAZED or vitreous wall tiling may be applied either to the outside or to the inside of a building, but when employed externally it is commonly termed terra-cotta or faience, and its application has been described in Vol. II, page 350.

The tiles or " biscuits " are glazed by dipping the face into the glazing liquid. The porous biscuit sucks out the water from the glaze as it passes towards the furnace, where the heat fuses the glaze on to the face of the tile. The grades of sorted tiles are known in the trade as *bests*, *commercials*, and *seconds*. Thus it is well to remember that second-quality tiles are not made from inferior materials or glazes, but are those which have sustained some slight blemishes during the process of manufacture.

Such blemishes must be distinguished from what is known as *crazing*, which is the appearance of a multitude of fine lines running in all directions on the glazed surface. The cause of crazing is the almost impossible problem of balancing the expansion of the materials of the tile and the glaze so that they move together when cooling. The appearance in no way affects the quality of the tile, and in many cases the effect is definitely pleasing when fixed on the wall.

To Test a Glazed Tile

A good test for the quality of a glazed tile is to place it on a stand over a tray containing strong hydrochloric acid, and insulate it from the atmosphere under a bell jar. After a period of twenty-four hours in the acid-laden atmosphere, the bell jar should be removed and the tile taken out and dried. A good glaze will show neither clouding nor iridescence after this treatment.

Stock Sizes

Ordinary glazed wall tiles may be obtained in sizes as large as 12 in. by 8 in., but these are expensive. The normal sizes range from 3 in. by 3 in. up to 6 in. by 6 in. or 9 in. by 3 in., with numberless intermediate sizes.

Besides plain tiling, various special sections are always obtainable, comprising angle heads, coves, and cappings, as well as skirting and dado mouldings.

In ordering a cove or a coved angle it must be remembered that the term 1-in. angle used to denote the size of the rounded portion of the tile usually means the over-all width across the curve, and not the radius.

Thus, on a $\frac{3}{8}$-in. thick tile, an external radius of $\frac{3}{4}$ in. is termed a 1-in. angle, and a $\frac{3}{8}$-in. internal angle is also so named.

Fixing

All tiling should be fixed upon a plumb-true Portland-cement screeding. Ordinary glazed tiles are made with a keyed back and are set in cement and sand, and afterwards pointed up in neat white cement or with Keene's.

Glass Tiles

Glass also is now employed as a wall tiling, and is available in a wide range of colours. While very large sheets can be obtained which are suitable for covering large areas in much the same manner as marble, the usual glass tile is a smaller product, generally about $\frac{1}{4}$ in. in thickness. Such tiles have a fire-polished non-porous surface, and are supplied in all sizes, the largest being in the neighbourhood of 18 in. by 12 in. For small rooms, such as bathrooms or sculleries, a larger tile will have the appearance of being out of scale.

Glass tiles can be had in a wide variety of shades, the most popular being black, shell-pink, eggshell green, agate green, ivory, turquoise blue, primrose, and red.

A very useful type of glass tiling is one consisting of small glass tiles fixed to a canvas backing, their edges cut so that they can be folded in either a concave or a convex curve. They are thus easily applied to rounded angles or to columns. The material is made up into panels 24 in. by 18 in., with tiles of three sizes, either 2 in. by $\frac{1}{2}$ in., 1 in. by 1 in., or 2 in. by 1 in., and is marketed in a variety of colours—white, pink, blue, or grey mirror-glass, and green, ivory, turquoise, and black opaque glass.

Fixing Glass Tiles

The most usual method of fixing glass tiles is by means of special mastic on to cement-rendered walls. Damp walls should be avoided, as the tiling on them will never be satisfactory. Approximately $\frac{1}{4}$ in. in thickness should be allowed for the mastic, and the edges of the glass tiles should be machine ground to give a true butt joint. The top edges of a dado can be finished with either a rounded, polished tile or a metal strip. Where tiles are prepared for screw fixing, such as in bathrooms or where access to pipes is necessary, it is better to provide the manufacturers with a drawing and have the holes drilled at the works than to do it on the job. Where glass tiles are so fixed with screws play must be allowed round the screw holes, and proper washers provided between the tile and the backing.

INDEX TO VOLS. I—IV

Accounts, Builders', iii. 529
Acoustics—
  architectural, ii. 145, 161
  of bandstands, ii. 161
  church, ii. 163
  cinema, i. 126 ; ii. 163
  concert hall, ii. 162
  film studio, ii. 164
  theatre, ii. 163
Aerodrome—
  buildings, i. 628
  layouts, i. 549
  markings, i. 549
  runways, i. 549
Aerodromes, i. 545, 628
Aggregates, concrete, iii. 180, 266
Air bricks, iv. 327
Air pollution, iv. 70
Airports, i. 545, 628
Air space about buildings, iv. 75
Alarm systems, fire, iv. 570
Altitude gauges, iv. 176
Aluminium paint for lagging, iv. 544
Aluminium wall facing, ii. 362
Arbitration, i. 165, 473
Arches—
  brickwork, iii. 300
  brickwork, estimating for, i. 142
  concentric, ii. 306
  inverted, ii. 312
  relieving brick, ii. 466
  setting out, iii. 301
  timber centering for, ii. 305
  transmission of thrust by, i. 16
  trimmer, ii. 450
Architect—
  factory, training of, i. 49
  laws for the, i. 161
  powers of, i. 164
Architect's certificate, i. 168
  fees, i. 161
  responsibility, i. 163
  sketch-plans for client, i. 227
  working drawings, i. 233
Architectural acoustics, ii. 145, 161
Architectural—
  design, influence of materials on, i. 432
  proportion, scale and rhythm in, i. 447
Architecture—
  Assyrian, i. 329
  Byzantine, i. 380
  early, i. 378
  Egyptian, i. 321
  Gothic, i. 394
  Greek, i. 333
  Persian, i. 330
  pre-Greek, i. 321
  prehistoric Greek, i. 330
  Renaissance, i. 411
  Roman, i. 353
  Romanesque, i. 385
Architraves, ii. 327 ; iii. 279
  window, iii. 26
Artesian wells, iv. 272, 458, 468
Art galleries, i. 513
Artificial stone, iii. 413
Asbestos—
  cable conduits, iii. 506
  cement, iii. 497
  ducts, iii. 506
  pipe fittings, iii. 506
  pressure pipes, iii. 502
  roofing, iii. 241 ; iv. 116
  sheets, decorated, iii. 507
  soil pipes, iii. 505
  " Turnall," wall board, iii. 63
  ventilators, iii. 506
  wall boards, iii. 498
Asbestos-felt, iii. 501
Asbestos-wood, iii. 498
Aspect, i. 482
  in house planning, i. 153
Asphalte—
  covered cornices, ii. 505
  damp-course, vertical, iv. 76
  for basements, iv. 76
  floors, ii. 57
  paths, iii. 317
  roofing, ii. 523 ; iv 192
  types of, iii. 194
  uses of, iii. 193
Assembly halls, i. 43
Assyrian architecture, i. 329
Asymmetrical plan, i. 12
Attics, insulating, iii. 61
Auditoria, reflecting characteristics of, ii. 150

Balconies, i. 25
Ball valves, iv. 562
Balustrades, ii. 541
Bandstands, ii. 161
Banks, i. 541
Basements—
  asphalte for, iv. 76
  damp-courses for, iv. 79
  deep, iv. 80
  drainage of, iv. 401
  lifting and pumping sewage from, iv. 461
  tanking of, iv. 76
Bases—
  stanchion, ii. 577 ; iii. 271, 426
  of walls, i. 15 ; ii. 577
Basins, lavatory, iv. 164, 359
Baths, iv. 163, 355
Batten flooring, iii. 326
Bay windows, i. 247
Beams—
  loads on, calculating, ii. 476
  reinforced concrete, ii. 133, 630
  resistance of, ii. 439
  steel, British standard sections for, ii. 603
  timber, ii. 417
Beds for plant, iii. 286
Bevels—
  purlins for, ii. 477
  roof, obtaining, ii. 476
Bidets, iv. 165, 255
Bills of quantities, iii. 530
Blinds, asbestos cement, ii. 401
Boiler flues, iii. 286
Boilers—
  for central heating, iv. 167
  fuels for, iv. 41
Bonding, brick, ii. 113 ; iii. 273
Book-keeping, iii. 512
Boundary fences and walls, ii. 375

Breeze bricks, iii. 492
Bressummers, ii. 465
Brick—
boundary walls, ii. 379
canopy, reinforced, iii. 488
chimney breasts, ii. 182
cornices, ii. 503
deliveries, iii. 274
diapers, ii. 182
fireplaces, ii. 182
flues, ii. 182
" Grip " partition, iii. 496
lintels, reinforced, iii. 495
moulded, copings, iv. 80
paths, iii. 319
quoins, ii. 180
relieving arches, ii. 466
string courses, ii. 503
walls, foundations for, iv. 187
Bricklaying, estimating for, i. 134
Bricks, iii, 436
air, iv. 327
breeze, iii. 492
cellular, iii. 490
concrete, iii. 486
enamelled, iii. 492
engineering, iii. 486
facing, iii. 486
flint-lime, iii. 491
glass, iii. 173, 489
glazed, iii. 492
insulatory, iii. 491
London stock, iii. 489
Multivent, iii. 491
plinth, ii. 180
salt-glazed, iii. 492
sand-lime, iii. 491
small, or briquettes, iii. 491
stock, iii. 486
types of, iii. 486
Brickwork—
arches, iii. 300
arches, estimating for, i. 142
bonding, ii. 113; iii. 273
bonds, diagonal and herring-bone, iii. 294
decorative, ii. 180; iii. 294
estimating for, i. 134
indents, iii. 291
new bondings to old, iii. 294
plinths in, ii. 179
pointing, iii. 289
racking back of, iii. 291
reinforced, iii. 488, 495
rubbers for, iii. 489
setting out, iii. 289
tools used in, iii. 301
toothing of, iii. 291
Brickwork—*Contd.*
wall finishing, ii. 177
walls, iii. 273
weathering bond in, ii. 179
Bridge, reinforced concrete, ii. 136
Bridging and shuttering, ii. 424
Briquettes, iii. 491
Builders, laws for, i. 173
Building—
accountancy of, iii. 529
a house, iii. 97, 113
air space about, iv. 75
construction, " Mopin " system of, ii. 561
law, i. 166
slabs, iii. 501
Societies, pool schemes, i. 254
speculative, i. 241
timbers, iii. 4, 129, 561
works, measurement of, iii. 532
Buildings—
acoustical requirements of, ii. 146
electrical services of, iv. 545
light, plywood for, iii. 467
old, reconditioning of, ii. 369
portable, iii. 470
timber, ii. 81, 97
Business—
organisation, iii. 511
premises, inspecting for faults, iii. 402
Butterfly roofs, i. 60
Byzantine architecture, i. 380

Calorifiers, iv. 173
Canopy, brick, reinforced, iii. 488
Carborundum on wet terrazzo, use of, ii. 53
Carpentry, estimating for, i. 443
Casein cement floors, ii. 19
Casement fittings, iii. 449
Casements, window, wood, ii. 410
Cast-iron—
wall facing, ii. 367
soil pipes, iv. 97, 450
Cavity walls, ii. 126, 178, 473; iv. 326
Ceilings, iv. 334
plaster board, iii. 71
plywood, iii. 471
Cellular bricks, iii. 490
Cement—
colouring of, iii. 635
compositions for lagging, iv. 541
floors, casein, ii. 19
mix for mosaic floors, ii. 58
oil, iv. 441
Portland, iii. 601; iv. 439
rapid-hardening, iii. 602
for reinforced concrete, iii. 178
Roman, iii. 603
rust, iv. 441
Cements, iii. 601; iv. 434
Centering—
timber, for arches, ii. 305
timber, for domes, ii. 311
Central heating (see Heating)
Central suction plants, iv. 279
Centrifugal pumps, iv. 103
Certificates—
architects', i. 169
of payment, iii. 554
Cesspools, roof, iv. 225
Chancel screens, iv. 513
Chases in walls, iii. 286
Chemical test of drains, iv. 48
Chimney—
breasts, ii. 182, 449
flues, ii. 449; iv. 40
stack, junction of roof with, iv. 124
Chimneys, ii. 187, 449
reconditioning, iii. 374
trimming for, ii. 533
Churches, i. 449; ii. 163; iv. 497
Chutes, rain-water, iv. 225
Cills—
artificial stone, iii. 415
copper, ii. 225
fixing, iii. 21
Ciment Fondu, iii. 603
Cinemas, i. 113; ii. 163
ventilating, iv. 275
Circulating pressure, iv. 146
Circulation, gravity, iv. 106
Cisterns—
feed, iv. 483
flushing, iv. 250, 566
storage, iv. 270, 558
Cistern-type electric water heaters, iv. 486
Clay tiles, iii. 228
Clerk of works—
duties of, iii. 247
hospital, iii. 248
progress reports and records, iii. 257
qualifications of, iii. 247

Closets, water, iv. 161, 243
Coils, panel, iv. 167
Colorphalt floors, ii. 57
Columns, reinforced-concrete, ii. 134, 633; iii. 427
Compressed-air plant, ii. 12
Concert halls, ii. 162
Concrete, ii. 613; iii. 180; iv. 433
  bricks, iii. 486
  colouring of, iii. 635
  dome, glass and, iii. 167
  encasing steelwork with, ii. 135; iii. 269
  flags, iii. 318
  floors, ii. 129, 398, 404, 611; iii. 403
  floors, glass and, iii. 162
  footings, ii. 577; iii. 426
  formwork for, ii. 129; iii. 191
  for foundations, iii. 266
  glass and, iii. 167
  joints in, iii. 189
  kerbs, iii. 316
  laying, estimating for, i. 97
  lintels, ii. 470
  manholes, iv. 138
  mixers, ii. 65; iii. 478
  mixing, iii. 185
  paths, iii. 315
  placing and tamping, iii. 187, 430
  protecting new, iii. 269
  reinforced, ii. 129, 611; iii. 117, 177, 417
  reinforced, beams, ii. 129, 630
  reinforced, bridge, ii. 136
  reinforced, code of practice for, ii. 611
  reinforced, columns, ii. 134, 633; iii. 427
  reinforced, floors, ii. 129, 404, 611; iii. 403
  reinforced, slabs, ii. 129, 626
  reinforcement bars, ii. 619; iii. 422
  runways for airports, i. 557
  on sites, ii. 577; iv. 71
  slab wall finish, ii. 354
  stairs, ii. 45, 134, 536
  stanchion bases, ii. 577; iii. 426
  steps, pre-cast, ii. 45
  surface treatment of, ii. 353; iii. 558
  swimming-pool construction, i. 508
Concrete—*Contd.*
  testing, ii. 192
  tiles, iii. 239
  walls, iii. 268
  walls, exterior facing, ii. 339
  water content of, iii. 185, 268
  water for, iii. 182; iv. 435
  work, forms for, ii. 76
  work, pre-cast, ii. 45, 404
  work, smooth finish, ii. 278
  working stress of ii. 613
Conduction of heat, iv. 9
Conduit electric cable—
  asbestos cement, iii. 506
  installations, iii. 122, 285; iv. 545
Contracts, variations to, iii. 557
Convection, iv. 10
Convectors, heating, electric, iv. 297
Cookers—
  domestic, iv. 308
  steam, iv. 387
Cooking equipment, iv. 385
Copings—
  moulded brick, iv. 80
  stone, iv. 80
Copper—
  cills, ii. 304
  cornices, ii. 303
  damp-proofing, ii. 304
  gutters, ii. 299
  roofing, ii. 291, 522; iii. 95
  welding, ii. 298
Copper pipes, iii. 81, 207
  bending, iii. 49; iv. 235
  brazing, iii. 90
  B.S. Specification, iii. 85
  compression joints, iii. 90
  joint testing, iii. 94
  welding, iii. 90
  Yorkshire capillary joint, iii. 90
Corbel water-closets, iv. 244
Cork flooring, ii. 23
Cornice mouldings, setting out, ii. 500
Cornices—
  asphalte-covered, ii. 505
  block, ii. 499
  brick, ii. 510
  classic, ii. 497
  composition of, ii. 498
  cramps for, ii. 505
  dentils for, ii. 498
  Egyptian, i. 16
  external, ii. 497
Cornices—*Contd.*
  fibrous-plaster, ii. 516
  internal, ii. 497
  lead-covered, ii. 505
  mediæval, i. 16
  metal, ii, 503
  modern, i. 16
  modillions for, ii. 498
  parts of, ii. 499
  plaster, ii. 497; iii. 40
  Renaissance, i. 16
  running, ii. 515
  sheet copper, ii. 303
  stone, ii. 504
  tailing down, ii. 507
  terra-cotta, ii. 509
  wood, ii. 503
Corrugated asbestos-covered sheets, iii. 244
Council housing schemes, i. 301
Country houses, i. 578
  drainage of, iv. 593
Course, drip-tile, iv. 80
Cradling, ii. 278
Cramps for cornices, ii. 505
Cranes, portable, ii. 15
Crazy-paving paths, iii. 318
Creasing, tile, iv. 80
Cullamix floor tiles, ii. 53
Cupboard fitments, iv. 312
Curb roofs, ii. 492
Cylinder hot-water supply systems, iv. 156
Cylinders, hot-water, lagging, iv. 541

Dados, ii. 331
Damper regulator, iv. 176
Dampness in walls, remedying, iii. 372, 627; iv. 190
Damp-proof courses—
  ii. 127, 177, 304; iii. 372, 627; iv. 78, 186
  asphalte, iv. 76
  for basements, iv. 79
  materials for, iv. 79
Damp-proofing, ii. 177, 127, 304; iii. 372, 627; iv. 76, 186
  by aeration, iv. 190
  basements, iv. 76, 627
  copper, ii. 304
  old walls, ii. 372
  sub-basements, iv. 76; iii. 627
Daywork sheets, iii. 261
Dead man, iii. 291
Decibel, ii. 145
Deflection, ii. 440
Dentils, ii. 498
Dermas floors, ii. 50

Design, general principles of, i. 7
Detached houses (see Houses)
Diapers, bricks, ii. 182
Diesel engine, ii. 10
Dimensions, working up, iii. 553
Domes—
  glass and concrete, iii. 167
  timber centres for, ii. 311
Door—
  locks, iii. 433
  openings in cavity walls, ii. 128
Doors—
  estimating for, ii. 440
  fire-resisting, ii. 400
  flush, ii. 559
  iron and steel, ii. 401
  wood, ii. 555
Doorways, design of, i. 16
Dormer windows, trimming for, ii. 533
Drainage—
  of basements and sub-basements, iv. 401
  by-laws and regulations, iv. 49, 518
  of country houses, iv. 593
  of estates, iv. 593
  of factories, iv. 605
  of farms, iv. 593
  gullies for, iv. 28
  iron, iv. 209
  land, iv. 72, 593
  one-pipe system of, iv. 517
  for paths, iii. 317
  pumps, subsoil, iv. 22
  rain-water, iv. 23, 225, 407
  of roofs, iv. 225
  schemes, iv. 17
  sewage, iv. 25, 72, 593
  subsoil, iv. 20, 71, 593
  surface-water, iv. 23
  waste-water, iv. 403
  work, iv. 434
Drain pipes—
  iron, iii. 284; iv. 450
  laying, iv. 141
Drains—
  cast-iron, iv. 209
  chemical test of, iv. 48
  gradients for, iv. 20
  house, planning of, iii. 18
  land, iv. 20
  laying, iv. 64
  laying, estimating for, i. 97, 129
  smoke test for, iv. 46, 99
Drains—*Contd.*
  stoneware, iv. 143
  testing of, iv. 44
  ventilation of, iv. 31
  water test of, iv. 45
Drain trenches, ii. 29; iv. 59, 64
Drawings, working, i. 233
Drenchers, ii. 400
Drip-tile course, iv. 80
Drying-plants, laundry, iv. 286
Dry rot, iii. 572; iv. 190
Ducts—
  in floors, iv. 556
  ventilating, iii. 287, 506, iv. 5
Dulrae heaters, iv. 303
Dust-removing systems, iv. 278

Eaves—
  finish, ii. 111, 271
  gutters, iv. 226
Egyptian architecture, i. 16, 321
Ejector, iv. 411
Electric—
  convector heaters, iv. 297
  fires, iv. 290
  heating, iv. 7, 289, 369
  heating, indirect, iv. 369
  lighting schemes, iv. 581
  panel heaters, iv. 299
  pumps, iii. 418
  tubular heaters, iv. 291
  water heaters, iv. 473
  wiring, iv. 545
Electrical services in buildings, iii. 122, 285; iv. 545
Emergency staircases, ii. 544
Enamelled bricks, iii. 492
Engineering bricks, iii. 486
Entrance gates, ii. 597
Estates, drainage of, iv. 593
Estimating—
  builder's, i. 97, 129, 433, 609; iii. 513
  for heating and ventilation installations, iv. 424
Excavating, ii. 28; iv. 64, 142
  estimating for, i. 97
Expansion tanks, iv. 111

Facing—
  aluminium, ii 362
  bricks, iii. 486
  cast-iron, ii. 367
  concrete, ii. 353; iii. 558
  glass, ii. 341
  stone, ii. 339
Factories, i. 49
Factory—
  drainage, iv. 605
  floors, i. 57
  heating and ventilation systems, i. 60; iv. 183
  roofs, i. 57
  sanitary accommodation, iv. 605
  sashes, iii. 18
  walls, i. 57
Faience, ii. 346
Fall ropes, ii. 3
Fanlight fittings, iii. 460
Fanlights, ii. 410
Fans, ventilating, iv. 274
Farms, drainage of, iv. 593
Feed and expansion tanks, iv. 111
Felt, asbestos, iii. 501
Fences, boundary, ii. 375
Fibre wall boards, iii. 53
Fibrous plaster, cornices, ii. 516
Figure, wood, iii. 577
Film studios, ii. 164
Filters, water, i. 509; iv. 529
Fire-extinguishing apparatus, iv. 570
Fire protection, construction for, ii. 397; iv. 541
Fireplaces, ii. 182, 454
Fires, electric, iv. 290
Flashings, iv. 118, 192
Flats, i. 17, 68
  electrical services of, iv. 550
  electric water heating in, iv. 484
  interiors of, i. 65
  kitchens for, i. 68; iv. 319
  lifts for, i. 23
  over shops, i. 31
  parking spaces for, i. 30
  playgrounds and gardens, for, i. 30
  staircases for, i. 28
  tenement, i. 72
Flint-lime bricks, iii. 491
Flitched bressummers, ii. 468
Flitches, steel, ii. 468
Floors—
  asphalte, ii. 57
  batten, iii. 326
  block, iii. 329
  casein cement, ii. 19
  cellular rubber, ii. 22
  colorphalt, ii. 57
  concrete, ii. 129, 404, 611; iii. 403; iv. 253
  concrete, piping in, iii. 285
  cork, ii. 23

Floors—*Contd.*
cullamix, ii. 53
damp-proofing for, iv. 187
dermas, ii. 50
double joist, ii. 273, 417
ducts in, iv. 556
factory, i. 57
finishes for kitchen, iv. 314
glass and concrete, iii. 162
granolithic, ii. 63
granwood, ii. 23
ground, iv. 332
hardwood, iii. 322
insulating, iii. 61
linoleum, ii. 21
Magnesite, ii. 49
marble, ii. 58
mosaic, ii. 58
Noel, ii. 27
parquetry, iii. 330
permanent, ii. 49
plastic, ii. 227
plywood, iii. 471
pre-cast concrete, ii. 404
quartered oak, ii. 27
reconditioning, iii. 373
reinforced concrete, ii. 129, 404; iii. 403
repairing, iii. 333
rubber, ii. 17, 225; iii. 145
running tubing in, iv. 555
single-joist, ii. 241, 417
softwood, iii. 324
sound-insulated, ii. 144
steel joist and concrete, ii. 398
stone, ii. 58
strutting for, ii. 253
terrazzo, ii. 50
tile, ii. 61
timber, laying, iii. 326
trimming for hearths, ii. 249
vulcanised, ii. 226
wood-block, ii. 23
wood joist, double, ii. 273, 417
wood joist, loads for, ii. 242, 418
wood joist, single, ii. 241, 417
Flues, ii. 182, 449
Flushing cisterns, iv. 250
Flushing valves, iv. 251
Footings, concrete, ii. 577; iii. 426
Forms—
circular, ii. 78
for concrete work, ii. 76, 129; iii. 191
steel, ii. 137
Formwork—
constructing, ii. 131
for girders, ii. 133
pressure on, ii. 129
for reinforced concrete bridges, ii. 136
scaffolding for, ii. 134
for stairs, ii. 134
suspended, ii. 135
timber for, ii. 130
Foundations—
on bad ground, ii. 581
brick bonding to, ii. 123
for brick walls, ii. 126, 577; iv. 187
concrete for, ii. 577; iii. 266
lifting land water from, iii. 417
piled, ii. 588
raft, ii. 581
setting out, iii. 78
of timber buildings, ii. 87
Fronts, all-glass, ii. 345
Fuels for central heating, iv. 41
Fume removal, iv. 278

Garages, i. 81
heating installations for, i. 94
petrol interceptor for, iv. 212
regulations and by-laws for, i. 96
Garden paths, iii. 315
Gas—
connectors, plug-in, iv. 205
escapes, testing for, iv. 199
fires, iv. 200
fitting, iv. 193
heating, iv. 6, 43
meters, iv. 195
pipes, sizes of, iv. 196
pressure gauge, iv. 199
supply services, iv. 193
water heating, iv. 202, 257
Gates, entrance, ii. 567
Gauges—
altitude, iv. 176
gas pressure, iv. 199
Gin wheel, ii. 3
Girders—
concrete, formwork for, ii. 133
reinforced concrete, ii. 133
steel, ii. 403
Glass—
all-, fronts for buildings, ii. 345
and concrete construction, ii. 525; iii. 167
Glass—*Contd.*
armour-plated, ii. 341
bricks, iii. 173, 489
facing, exterior wall, ii. 341
partitions, iii. 171
pressed, iii. 161
roofs, iii. 164
tiles, iv. 626
vitrolite, ii. 342
walls, iii. 169
"Glass-crete," ii. 525
Glazed bricks, iii. 492
Glazing—
estimating for, i. 626
fire-resisting, ii. 400
Gothic architecture, i. 394
Gradients, for drains, iv. 29
Grain, wood, iii. 577
Granites, iii. 362
Granolithic floors, ii. 63
Granwood floors, ii. 23
Gravity circulation, iv. 106
Greek architecture, i. 333
Greek town planning, i. 352
"Grip" partition bricks, iii. 496
Ground—
loads on, ii. 636
water on sites, iv. 70
Ground air on sites, iv. 70
Grounds for finishings, iii. 279
Grouting—
for stanchion bases, iii. 271
for steelwork, iii. 271
Gullies—
cast-iron, iv. 210
for drainage, iv. 28
flushing, iv. 210
yard, iv. 211
Gunite process, iii. 636
Gutters—
asbestos-cement, iv. 230
capacity of, iv. 227
choked, iv. 191
copper, ii. 299
parallel, ii. 530; iv. 125
secret, iv. 125
tapering, ii. 532; iv. 125
zinc, iv. 230
Gymnasiums, i. 283
Gypsum cements, ii. 601

Halls—
concert, ii. 162
ventilating, iv. 275
Handrails, ii. 541
Hardwood floorings, iii. 329
Hardwoods—
buying, iii. 16
costs of, iii. 15

Hardwoods—*Contd.*
Empire, iii. 10, 584
grading of, iii. 4
home-grown, iii. 8, 584
measuring, iii. 6, 568
seasoning of, iii. 16, 568
shipping, iii. 4, 568
types of, iii. 8, 584
waste in conversion of, iii. 15
Hearths, ii. 249, 254, 450
Heat—
insulation, ii. 103
losses from hot-water circulation, iv. 145, 493
losses of heating systems, iv. 12, 302
losses, ventilation, iv. 14
Heaters—
electric, iv. 291
unit, iv. 183
Heating—
calculations, iv. 12, 302
central, by hot water, iv. 6, 33, 103, 167, 369
costs of, iv. 428
electrical, iv. 7, 289, 369
of cinemas, i. 122
of factories, i. 60; iv. 183
fuels for, iv. 41
gas, iv. 6, 43
installation, estimating for, iv. 424
installation for garages, i. 94
installation, specifications for, iv. 424
installations, builders' work for, iv. 377
insulating materials for, iv. 10
panel, iv. 167
pipes, sizes of, iv. 105
schools, i. 287
steam, iv. 6, 177, 398
by steam, iv. 6, 177, 398
stoves, iv. 3
swimming pools, i. 512
systems, circulating pressure of, iii. 35
systems, heat losses of, iv. 12
systems, hot-water, accelerated circulation for, iv. 157
thermal storage, iv. 7, 370
warm-air, iv. 3
"Hilmor" pipe bender, iii. 49
Hips, weathering, iv. 125
Hoardings, ii. 176
Hoists, ii. 7
Hopper windows, ii. 409
Hospital—
clerk of works, iii. 248
sinks, iv. 250
Hotels, i. 193
restaurants of, i. 212
Hot-water supply systems—
accelerated, iv. 157
combined fuel-fired and electric, iv. 485
cylinder, iv. 81, 156
secondary circulation, iv. 146
tank, iv. 81
House—
building, iii. 97, 113
inspecting for faults, iii. 393
Houses—
Council, i. 289
country, i. 578
detached, i. 145, 225, 481, 577
drainage of, iv. 593
grouped, i. 289
isolated, drainage of, iv. 593
sectional, ii. 93
semi-detached, i. 243
sites for, iv. 67
speculative, i. 241
street, small, i. 561
terrace, i. 242, 561
Housing—
Council schemes, i. 301
overcrowding standards, i. 301
schemes, i. 289
Hydrants, iv. 573

Indents, iii. 291
Inspecting property for faults, iii. 385
Inspection chambers, iv. 129
Insulating—
attics, iii. 61
board, iii. 57
board as plaster base, iii. 58
flat roofs, ii. 527; iii. 62
floors, iii. 61
materials, iv. 10
pitched roofs, iii. 62
Insulation, sound-, ii. 141
Insulatory bricks, iii. 491
Intercepting traps, iv. 528
Interceptors, iv. 137
Iron, iv. 447

Jacks, ii. 7
Joggled-brick lintels, ii. 475
Joinery, estimating for, i. 433
Joists—
bridging, ii. 275, 424
floor, ii. 241
laying, ii. 443
strutting, ii. 424
timbers for, ii. 419
trimmer, ii. 427, 434
trimming, ii. 427, 434
wood, loads on, ii. 417
wood, selecting, ii. 417
wood, spacing, i. 419
wood, strength of, ii. 417

King-post roof truss, ii. 444
Kitchen cabinets, iv. 410
Kitchens—
colour, iv. 318
equipment of, iv. 309, 385
for flats, iv. 319
floor finishes for, iv. 314
layout of, iv. 385
lighting, iv. 318, 385
planning, i. 155; iv. 305
ventilation of, iv. 319
wall finishes for, iv. 315
for working-class flats, iv. 321

Lagging hot-water tanks, pipes, and cylinders, iv. 541
Lamella roofs, ii. 112
Land drainage, iv. 20, 72
Landing-areas of aerodromes, i. 545
Landings on stairs, ii. 534
Lantern lights, ii. 523
Laths—
gypsum, iii. 48
metal, iii. 37
Laundries—
drainage of, iv. 612
drying plant for, iv. 286
Lavatory basins, iv. 164, 359
Law courts, i. 46
Laws—
for the architect, i. 161
for the builder, i. 173
Lead, iv. 442
compounds, iv. 444
covered cornices, ii. 505
red, iv. 445
roofing, iv. 119
traps, iv. 442
white, iv. 444
Lenses, circular, iii. 167
Libraries, i. 513
Lifting equipment, builders', ii. 3
Lift wells, iii. 286

Lifts—
for flats, i. 23
for hotels, i. 200
for office buildings, i. 535
sewage, iv. 415
for shops, i. 601
Lighting—
gas, points for, iv. 205
kitchens, iv. 318, 385
picture, i. 519
schemes, electric, iv. 581
Seager system of, i. 519
Lime plaster, iii. 33
Limes, iii. 598
Limestones, iii. 363
Limewash for stocks, i. 239
Linings, fixing, ii. 323; iii. 279
Linoleum floors, ii. 21
Lintels, ii. 465
brick, reinforced, iii. 495
built-up, ii. 467
in cavity walls, ii. 473
concrete, ii. 470
flat brick, ii. 475
joggled-brick, ii. 475
pre-cast, ii. 472
reinforced concrete, iii. 427
rolled-steel-joist, ii. 473
stone, ii. 469
wood, ii. 466
Loads—
on beams, calculating, ii. 476
dead, ii. 621
on floors, ii. 418
on ground, ii. 636
live, ii. 622
on timbers, ii. 418
on wood joists, ii. 418
Local surveyor, submitting plans to, iii. 76
Locks, door, iii. 433
London stock bricks, iii. 489

Magnesite floors, ii. 49
Mahogany (see Woods)
Manholes, iv. 129
estimating for, i. 133
testing of, iv. 46
Mansard roofs, ii. 371, 492
Marble, iii. 368
floors, ii. 58
imitation, fixing, iii. 158
Materials, insulating, iv. 10
Measurement of building works, iii. 532
Measuring hardwoods, iii. 6
Metaforms, ii. 137
Meters, gas, iv. 195
Modillions, ii. 498
"Mopin" system, ii. 661
Mortars, iii. 604; iv. 438
Mosaic floors, ii. 58
Multivent bricks, iii. 491
Museums, i. 513

Noel floors, ii. 27
North light saw-tooth roof, i. 60

Oak (see Woods)
Office buildings, i. 529
electrical services of, iv. 552
Oil heating, iv. 42, 184
One-pipe system of drainage, iii. 284; iv. 97
Opera houses, ii, 163

Painting, estimating for, i. 623
Panel heaters, electric, iv. 299
Panel-heating system, iv. 167
Pantiles, i. 239
asbestos-cement, iii. 245
Paperhanging, estimating for, i. 626
Parapets, weathering, iv. 80
Partition blocks, iii. 494
Partitions—
glass, iii. 171
plywood, iii. 470
slab, estimating for, i. 144
Partition walls, iv. 328
Party-wall awards, i. 167
Paths—
drainage for, iii. 317
garden, iii. 315
Paving, crazy, iii. 318
Payment, certificates of, iii. 554
Pebble-dash, iii. 634
Persian architecture, i. 330
Petrol interceptors, iv. 212
Picture lighting, i. 519; iv. 587
Piled foundations, ii. 588
Pipe expansion, allowing for, iv. 440
Pipes—
cast-iron, soil, iv. 97, 450
cold-feed, iv. 484, 566
copper, iii. 81, 207; iv. 235
discharging power of, iv. 147
heat loss from, iv. 91
hot-water, iv. 568
hot-water fittings, iv. 39
lagging, iv. 541
overflow, iv. 163
pressure, asbestos-cement, iii. 502
Pipes—*Contd.*
pressure loss in, iv. 154
rain-water, iv. 191, 225, 527
rate of outflow from, iv. 151
stoneware drain, estimating for, i. 129
testing, iv. 97, 99
trap-ventilating, iv. 577
waste and soil, iv. 102, 450, 577
water, sizes of, iv. 37
Pitch of roof, ii. 264
Planning, principles of, i. 7
Plans—
sketch-, architects', i. 227
submitting to local surveyor, iii. 76
Plaster—
fibrous, ii. 516
moulding, iii. 40
wall boards, iii. 65
Plaster board, use of, iii. 48
Plastering, ii. 497; iii. 34, 124, 281
brickwork, iii. 34
cornices, ii. 497; iii. 40
estimating for, i. 610
lath ceilings, iii. 34
Plasters, iii. 33, 280
Playgrounds for flats, i. 30
Plenum system, iv. 4
Plinths, brickwork, ii. 179
Plumbing work, iii. 283
estimating for, i. 617
Plywood—
floors, iii. 471
metal-faced, iii. 477, 597
partitions, iii. 470
types and sizes of, iii. 472, 596
walls, iii. 53, 470
Pointing brickwork, iii. 289
Pollution of water, iv. 471
Portland cement, iii. 601; iv. 439
Pressed glass, iii. 161
Progress—
reports and records of clerk of works, iii. 257
schedules, ii. 193; iii. 257
Proportion in architecture, i. 447
Pulley blocks, ii. 4
Pumps—
accelerator, iv. 103
centrifugal, iv. 103, 460
electric, iii. 418
for lifting land-water from foundations, iii. 417
sewage, iv. 414
subsoil drainage, iv. 22

Purlins, ii. 369, 445, 480
bevels for, ii. 477
design of, ii. 487

Quantities, bills of, iii. 530
Quantity surveying, iii. 530
Queen-post trusses, ii. 492
Quoins, brick, ii. 180

Racking back brickwork, iii. 291
Radiators—
heat transmission of (table), iv. 34
hospital, iv. 33
hot-water, iv. 298
luminous, iv. 289
steam, iv. 298
Rafters—
calculating spacing of, ii. 476
design of, ii. 484
Raft foundations, ii. 581
Rain-water—
chutes, iv. 225
drainage, iv. 23, 225, 407
filtration of, iv. 454
goods, asbetos-cement, iii. 505
outlet pipes for, iv. 225
pipes, iv. 191
storage, iv. 24, 455
water supply by, iv. 453
Reconditioning of old buildings, iii. 369
Reconstructed stone, iii. 413
Red lead, iv. 445
Refrigerators, iv. 308
Reinforced concrete (see Concrete)
Reinforcing rods, iii. 422
Relieving arches, brick, ii. 466
Renaissance architecture, i. 16, 411
Rendering walls, iii. 634
Requisitions, iii. 515
Rhythm in architecture, i. 447
Roman architecture, i. 353
Romanesque architecture, i. 385
Roman town planning, i. 363
Roof—
bevels, obtaining, ii. 476
erection, iii. 114
factory, north light saw-tooth, i. 60
house, design of, i. 160
Roof—*Contd.*
parts of, ii. 264
trusses, composite, iii. 493
trusses, king-post, ii. 444
trusses, pre-cast, iii. 428
trusses, stress diagrams for, ii. 488
Roofing—
asbestos-cement, iii. 501
241 ; iv. 116
asphalte, ii. 523 ; iv. 192
copper, ii. 291, 522 ; iii. 95 ; iv. 119
lead, iv. 119
materials, ii. 480
zinc, ii. 522 ; iv. 119
Roofs—
butterfly, i. 60
collar-and-tie, ii. 269
collar-tie, ii. 269
couple, ii. 268
couple close, ii. 268
curb, ii. 268, 492
drainage of, iv. 225
eaves finish for, iv. 271
factory, i. 57
flat, ii. 520 ; iii. 62
glass and concrete, iii. 164
house, i. 160
insulating, ii. 527 ; iii. 62
Lamella, ii. 112
lean-to, ii. 267
Mansard, ii. 371, 492
pitched, insulating, iii. 62
pitches for, ii. 209, 218, 264
purlins for, ii. 369, 445
reconditioning, iii. 375
single, ii. 265
single mansard, ii. 371
slate, ii. 257 ; iii. 209 ; iv. 115
thatch, iv. 118
tile, ii. 209 ; iv. 117
valley, ii. 369
weathering, iv. 114, 122
wood shingle, iii. 221
Ropes, fall, ii. 3
Roughcasting, iii. 634
Rubber—
coverings, iii. 150
flooring, ii. 17, 225 ; iii. 145
sheets for walls, iii. 150
stair treads, iii. 145
Rubbers for brickwork, iii. 489
Runways of airports, i. 546

Salt-glazed bricks, iii. 492
Sand, iv. 437
Sand, for reinforced concrete, iii. 178
Sand-lime bricks, iii. 491
Sandstones, iii. 365
Sanitary fittings, iv. 241, 353, 574
Sanitary surveying, iv. 44, 97, 161, 186, 270, 363
Sashes, for windows, ii. 406 ; iii. 449
Sash pulleys, fixing, iii. 449
Scaffolding—
estimating for, i. 135
for formwork, ii. 134
for interiors, ii. 43
steel, ii. 33
Scale in architecture, i. 447
Schedules, time and progress, ii. 193
Schemes, housing, i. 289
Schools, i. 12, 257 ; ii. 273
drainage of, iv. 609
heating and ventilation of, i. 287
Seager system of lighting, i. 519
Secondary circulations, hot water, supply, designing, iv. 145
Sectional houses, ii. 93
Semi-detached houses, i. 243
Setting out—
brickwork, iii. 289
buildings, iii. 76, 264, 289
cornice-mouldings, ii. 500
for foundations, iii. 78
Sewage—
disposal, iv. 593
drains, iv. 25, 53, 73, 411, 593
lifting and pumping from basements, iv. 411
lifts, iv. 415
pumps, iv. 414
Sewers, back-flooding from, iv. 419
purification, iv. 602
Shear, resistance to, ii. 424
Shingle, wood, roofs, iii. 221
Shop fronts, i. 32, 605 ; iii. 605
metal, iii. 605
Shops, i. 593
electrical services of, iv. 546
flats over, i. 31
Shoring, ii. 167
Shuttering, iii. 277
Shutters, rolling, ii. 401
Sinks, iv. 165, 250, 309, 353
hospital, iv. 250
slop, iv. 248

Siphonic water closets, iv. 244
Sites—
concrete on, ii. 577 ; iv. 71
factory, i. 54
for flats, i. 20
of garages, i. 81
of hotels, i. 195
for housing schemes, i. 289
school, i. 259
suitability of, iv. 65, 113, 593
Skirtings, ii. 385
Slabs—
building, iii. 501
reinforced-concrete, design of, ii. 626
Slate roofs, ii. 257 ; iii. 209 ; iv. 115
Slates—
asbestos-cement, iii. 241
calculating quantities of, iii. 215
defects in, iv. 192
grading of, iii. 214
sizes of, iii. 216
types of, iii. 209
Slating—
estimating for, i. 614
methods of, ii. 257
Sleeper walls, iii. 120 ; iv. 333
Slop sinks, iv. 248
Soakage pits, iv. 601
Soakers, iv. 123
Softwoods—
branding of, iii. 137
defects in, iii. 142, 573
grading of, iii. 137
types of, iii. 131, 578
Soil—
made, iv. 67
natural, iv. 66
pressure on timbers, ii. 28
Soil pipes—
asbestos-cement, iii. 505
cast-iron, iv. 97, 576
one-pipe system of, iv. 97, 523
Soils, influence on health of, iv. 67
Sound-absorbing coefficients, ii. 155
Sound-insulation, ii. 141
Specifications—
architects', ii. 237
for heating installation, iv. 427
for ventilating installation, iv. 427
Speculative building, i. 241
Spiral staircases, ii. 542
Sprinkler system, iv. 570
Stack-room, i. 526
Stair—
strings, ii. 396, 534
treads, rubber, iii. 145
Staircases, ii. 534
circular, ii. 538
emergency, ii. 544
for flats, i. 23
for hotels, i. 200
for office buildings, i. 535
for shops, i. 600
spiral, ii. 542
Stairs—
concrete, ii. 45, 134, 536
estimating for, i. 443
formwork for, ii. 134
Stanchion bases, ii. 577 ; iii. 271, 426
Stanchions, rolled-steel, ii. 398
"State of works" descriptions, iii. 257
Staybrite, iii. 605
Steam heating, iv. 6, 173, 177, 398
Steam pipes, sizes of, iv. 177, 399
Steam traps, iv. 179
Steel—
beams, British standard sections for, ii. 603
stresses, permissible, ii. 612
Steelwork—
encasing with concrete, ii. 135 ; iii. 269
fire protection of, ii. 403
grouting for, iii. 271
structural, ii. 593
Still-room equipment, iv. 396
Stock bricks, iii, 486
Stone—
artificial or reconstructed, iii. 413
blocks, lifting, iii. 348
boundary walls, ii. 381
copings, iv. 80
cornices, ii. 503
facing, ii. 339
fixing lead to, iii. 358
flag paths, iii. 317
floors, ii. 58
lintels, ii. 469
for paving and steps, iii. 277
Portland, iii. 275
staircases, ii. 536
string courses, ii. 503
substitutes, iii. 277
Stones—
building, finishings on, iii. 345
Stones—*Contd.*
fixing and securing, iii. 353
natural, iii. 353
preserving, iii. 361
testing, iii. 360
Stonework—
operators, iii. 276
setting, iii. 350
Stop-valves, iv. 181
Storage—
cisterns, iv. 558
tanks, iv. 455, 558
thermal heating, iv. 7
water heaters, electric, iv. 473
water heaters, gas, iv. 265
Stores, i. 593
electrical services of, iv. 546
Stoves, heating, iv. 3
Street houses, small, i. 561
String courses, ii. 502
Strings, ii. 540
Strutting, for floors, ii. 276, 253, 424
Stucco, iii. 634
Sub-basements, iv. 80
drainage of, iv. 401
Subsoil, drainage, iv. 20, 71, 594
Suction, central, plants, iv. 279
Surveying—
quantity, iii. 530
sanitary, iv. 363
Surveyor—
local, submitting plans to, iii. 76
quantity, iii. 530
Swimming pools—
chemical treatment of, i. 510
equipment of, i. 509
planning and designing, i. 497

Tanking basements, iv. 76
Tanks—
feed and expansion, iv. 111
hot-water, lagging, iv. 541
storage, iv. 81, 558
Tapering gutters, iv. 125
Taps, water, iv. 565
Tar-mac paths, iii. 317
Tenement flats, i. 72
Terrace houses, i. 242
Terraces, paving, iii. 319
Terra-cotta, ii. 346
cornices, ii, 503
tile floors, ii. 61
walls, ii. 386
Terrazzo floors, ii. 50

Thatch roofs, iv. 118
Theatres, i. 305 ; ii. 163
Thermal storage heating, iv. 7, 370
Thermostats, iv. 303
Tile—
creasing, iv. 80
drip-, course, iv. 80
floors, ii. 61
Tiles—
floor, ii. 53
roof, asbestos-cement, iii. 245 ; iv. 116
roof, choosing, iii. 237
roof, clay, iii. 225
roof, concrete, i. 240
roof, defects in, iv. 192
wall, interior, iv. 625
Tiling—
roof, estimating for, i. 616
roof, plain, i. 240 ; ii. 209 ; iii. 232
single-lap, roof, ii. 218 ; iii. 117, 234
Timber buildings, ii. 81, 97
Timbers, building, iii. 4, 129, 561. (See also Hardwoods, Softwoods, and Woods)
Time and progress schedule, ii. 193 ; iii. 262
Tools, small, for builders, ii. 545
Toothing, brickwork, iii. 291
Town halls, i. 33
Town planning—
Greek, i. 352
Roman, i. 363
Towel-rail calculations, iv. 150
Transom lights, ii. 410
Trap design, iv. 574
Traps—
intercepting, iv. 528, 574
lead, iv. 442
siphon, iv. 405
steam, iv. 179
Trap ventilating pipes, iv. 576
Trench excavation, ii. 28 ; iv. 64, 142
estimating for, i. 97
Trenches, drain, ii. 29 ; iv. 59, 64
Trimmer—
arches, ii. 450
joists, ii. 427, 434
Trimming, ii. 520
for chimneys, ii. 533
for dormer windows, ii. 533
joists, ii. 244, 427, 434
Trusses—
king-post roof, ii. 444
pre-cast roof, iii. 428
queen-post, ii. 492
roof, stress designing, ii. 488
"Turnall" asbestos wall board, iii. 63

Underpinning, iii. 274
Unit heaters, iv. 183
Urinals, iii. 284 ; iv. 252

Vacuum-cleaning plant, central, iv. 284
Valley roofs, ii. 369
Valleys, weathering, iv. 125
Valves—
ball, iv. 562
flushing, iv. 251
Valve water-closets, iv. 244
Veneers, iii. 595
Ventilation, iii. 286 ; iv. 5, 319, 274, 424
Vitrolite, ii. 342

Wages book, iii. 517
sheets, iii. 517
Wall—
brick, bonds, ii. 113
concrete, work, iii. 268
finishes, exterior, i. 237 ; ii. 337, 353 ; iv. 329
finishes, interior, iv. 315, 625
finishings, brickwork, ii. 177
tiling, interior, iv. 625
Wall boards, iii. 63, 498
Walls—
boundary, ii. 379
brick, ii. 113, 126, 178, 379 ; iv. 326
brick, foundations for, ii. 577 ; iv. 187
brick, lengthening, iii. 294
cavity, ii. 126, 178, 473 ; iv. 326
cavity, lintels in, ii. 473
chases in, iii. 286
concrete, facing, ii. 353 ; iii. 558
cornices for, ii. 497
damp-proofing for, ii. 127, 177, 304 ; iii. 372, 627 ; iv. 76, 187
design of, i. 15
factory, i. 57
glass, iii. 169
partition, iv. 328
pointing, iii. 289
reconditioning, iii. 371
rendering, iii. 634
Walls—*Contd.*
sleeper, iii. 120 ; iv. 333
sound-insulated, ii. 143
of swimming pools, i. 508
terra-cotta for, ii. 346
ventilating, iv. 327
water-proofing, iii. 631 ; iv. 189, 471
Waste pipes, iv. 102, 523
Waste-water drainage, iv. 403
Water—
aeration of, i. 510
analysis of, iv. 347
closets, iv. 161, 243
filters, iv. 529
hardness, iv. 347
heaters, electric, iv. 473
heaters, gas, iv. 258
pollution of, iv. 471, 593
proofing walls, iii. 631 ; iv. 189, 471
raising, iv. 459
sampling, iv. 472
softeners, iv. 337
sterilisation of, iv. 533
storage cisterns, iv. 270
supply, public, iv. 529
supply, rain-water, iv. 543
supply, well, iii. 382 ; iv. 455
Wells, iii. 382 ; iv. 272, 458, 465
White lead, iv. 444
Window area required, iv. 335
Windows—
bay, i. 247 ; iii. 32
design of, i. 16, 159
dormer, trimming for, ii. 533
factory, iii. 18
fittings for, iii. 449
metal, iii. 17
reconditioning, iii. 381
wood-framed, ii. 406
Wood—
asbestos, iii. 498
buildings, ii. 81
Woods—
(see also Hardwoods and Softwoods)
conversion of, iii. 565
defects in, iii. 571
figure of, iii. 577
grain of, iii. 129, 577
marketing of, iii. 567
preservation of, iii. 570
seasoning of, iii. 568
selecting, iii. 563
Working-class houses, i. 299

Zinc—
gutters, iv. 230, 446
piping, iv. 447
roofing, ii. 522 ; iv. 119
sheets, iv. 446

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